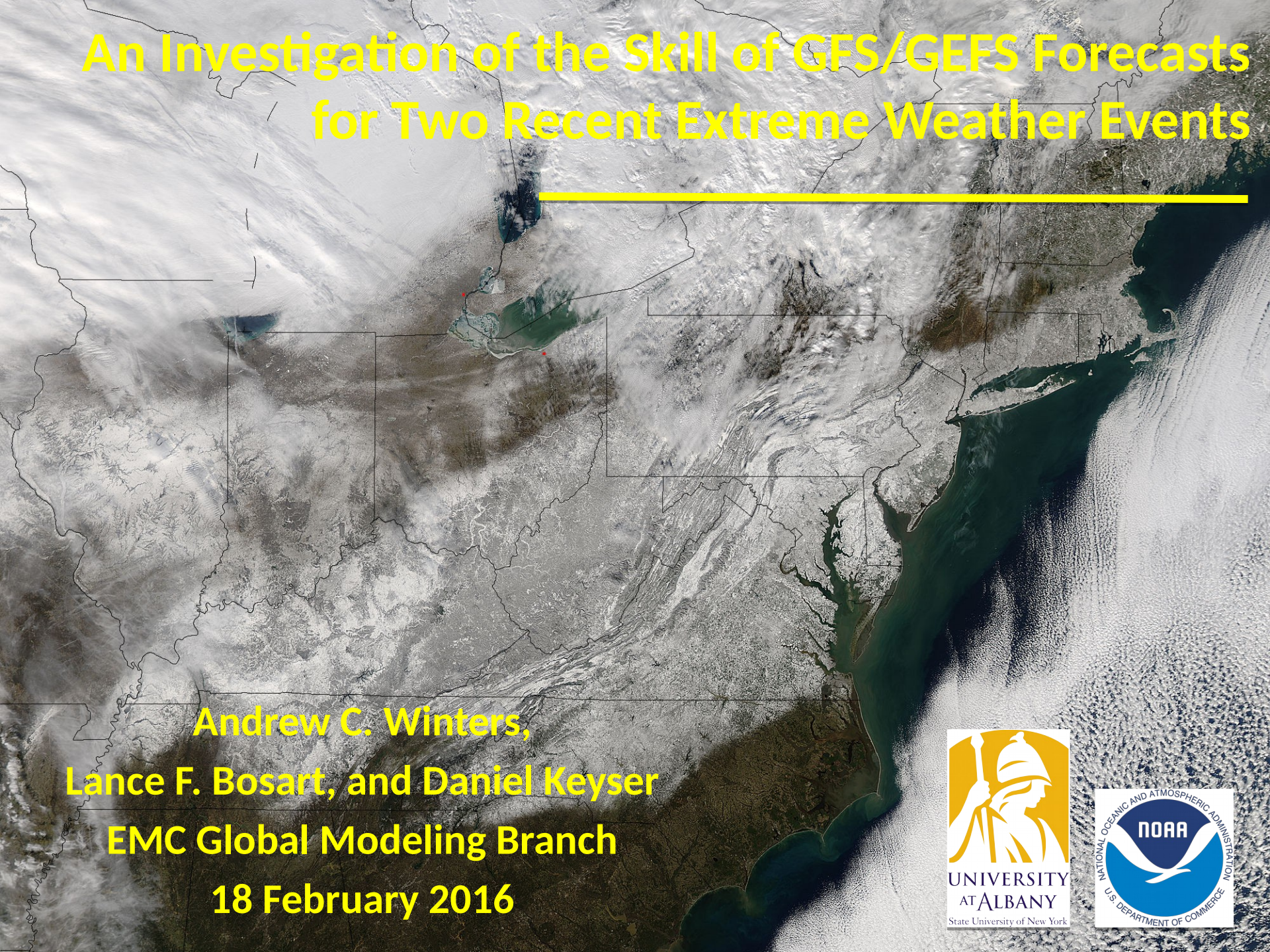
An Investigation of the Skill of GFS/GEFS Forecasts for Two Recent Extreme Weather Events



Andrew C. Winters,
Lance F. Bosart, and Daniel Keyser
EMC Global Modeling Branch
18 February 2016

Motivation

One or several **extreme weather events (EWEs)** can have a substantial impact on seasonal temperature and precipitation statistics.

Jamie Henn - Twitter

Motivation

One or several **extreme weather events (EWEs)** can have a substantial impact on seasonal temperature and precipitation statistics.

EWEs need to be considered in describing and understanding the processes that operate at the weather–climate intersection.

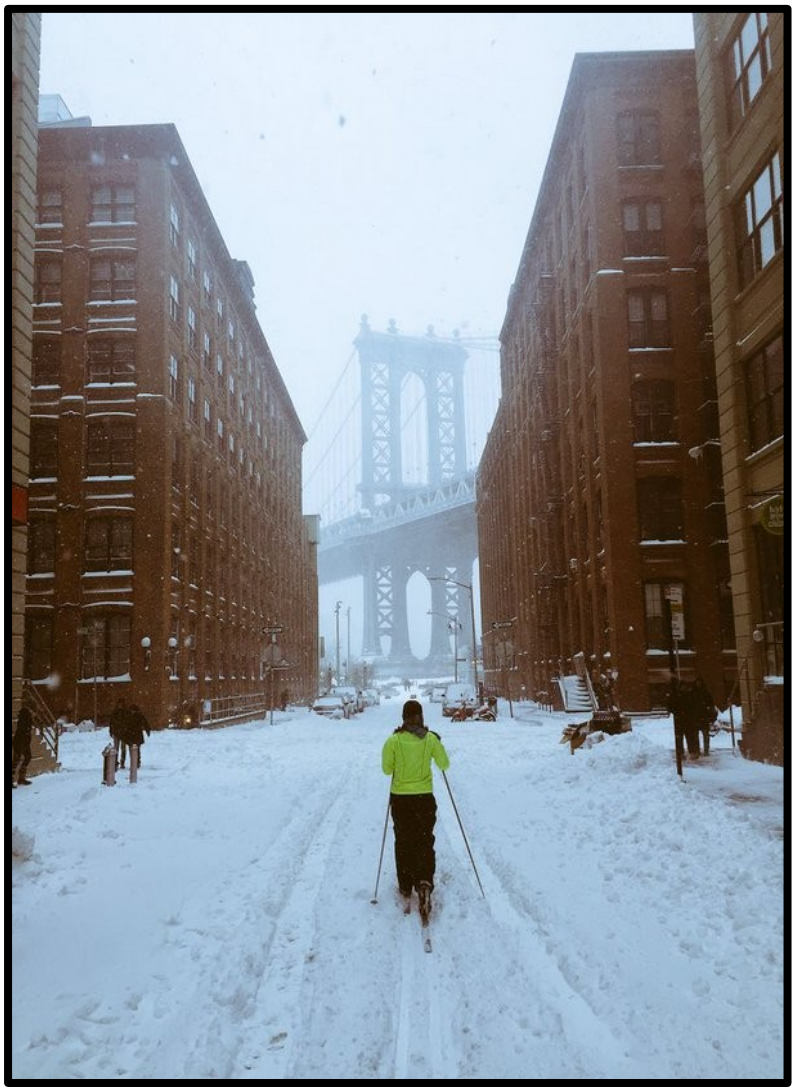
Jamie Henn - Twitter

Motivation

One or several **extreme weather events (EWEs)** can have a substantial impact on seasonal temperature and precipitation statistics.

EWEs need to be considered in describing and understanding the processes that operate at the weather–climate intersection.

An increased understanding of **EWEs** has the potential to improve temperature and precipitation forecasts for the 8–10 day period.



Jamie Henn - Twitter

Objectives

1) To identify the governing atmospheric flow patterns essential to the evolution of two recent EWEs:

- **22–24 January 2016 Blizzard**
- **22–23 December 2013 Ice Storm**

Objectives

1) To identify the governing atmospheric flow patterns essential to the evolution of two recent EWEs:

   - **22–24 January 2016 Blizzard**
   - **22–23 December 2013 Ice Storm**

2) To evaluate the skill of operational GFS and GEFS forecasts for these events.

Objectives

1) To identify the governing atmospheric flow patterns essential to the evolution of two recent EWEs:

   - **22–24 January 2016 Blizzard**
   - **22–23 December 2013 Ice Storm**

2) To evaluate the skill of operational GFS and GEFS forecasts for these events.

3) To outline a research plan that desires to systematically identify, classify, and evaluate EWEs.

22–24 January 2016 Blizzard

~1,125,000 km^2 affected.

24 million people resided in locations with **>50 cm** of snow.

~500,000 lost power along the East Coast.

55 fatalities attributed to the storm.


NOAA

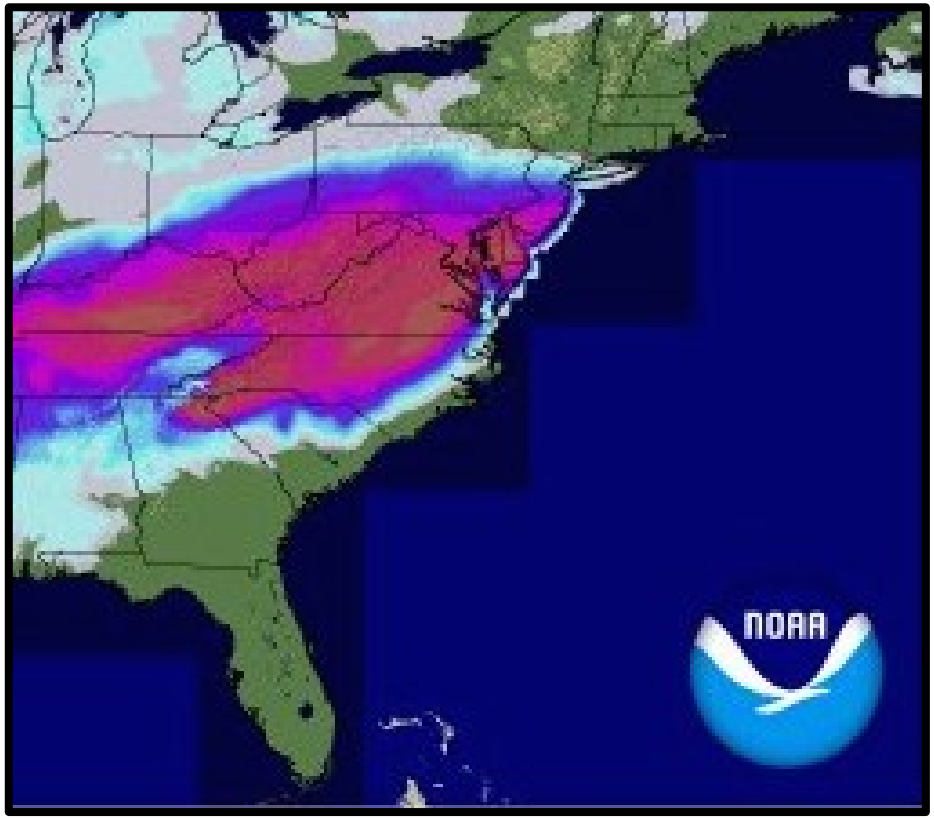

Jarekt


A. Hink

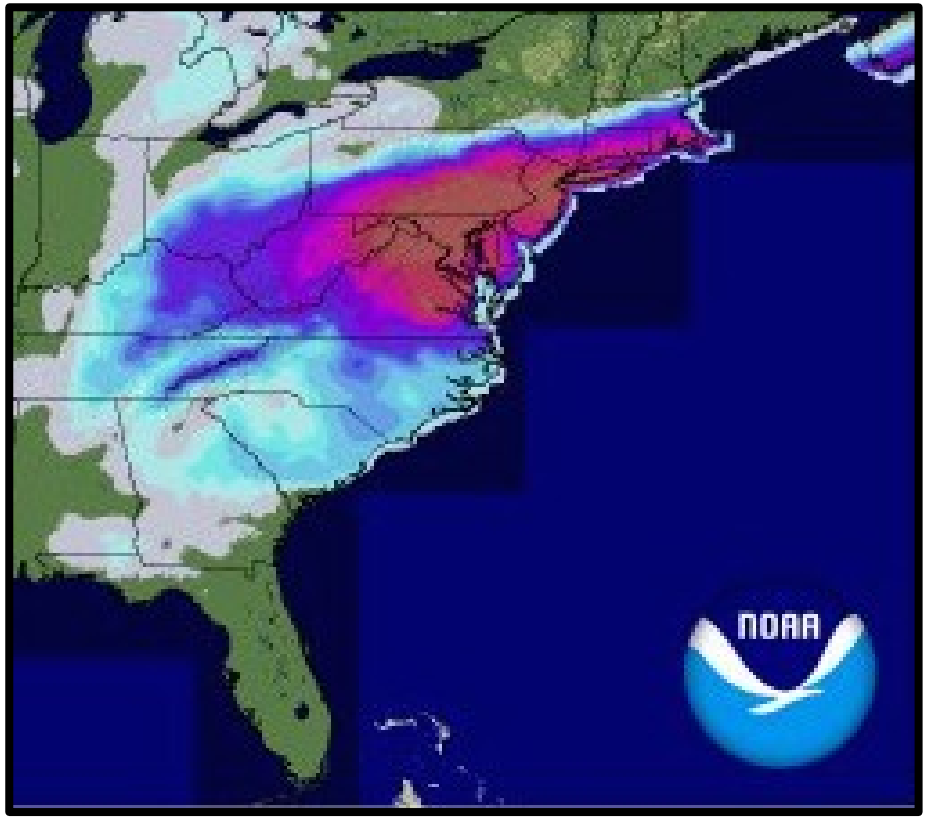
22–24 January 2016 Blizzard

24-h Snow Accumulation

Ending: 0600 UTC 23 January 2016

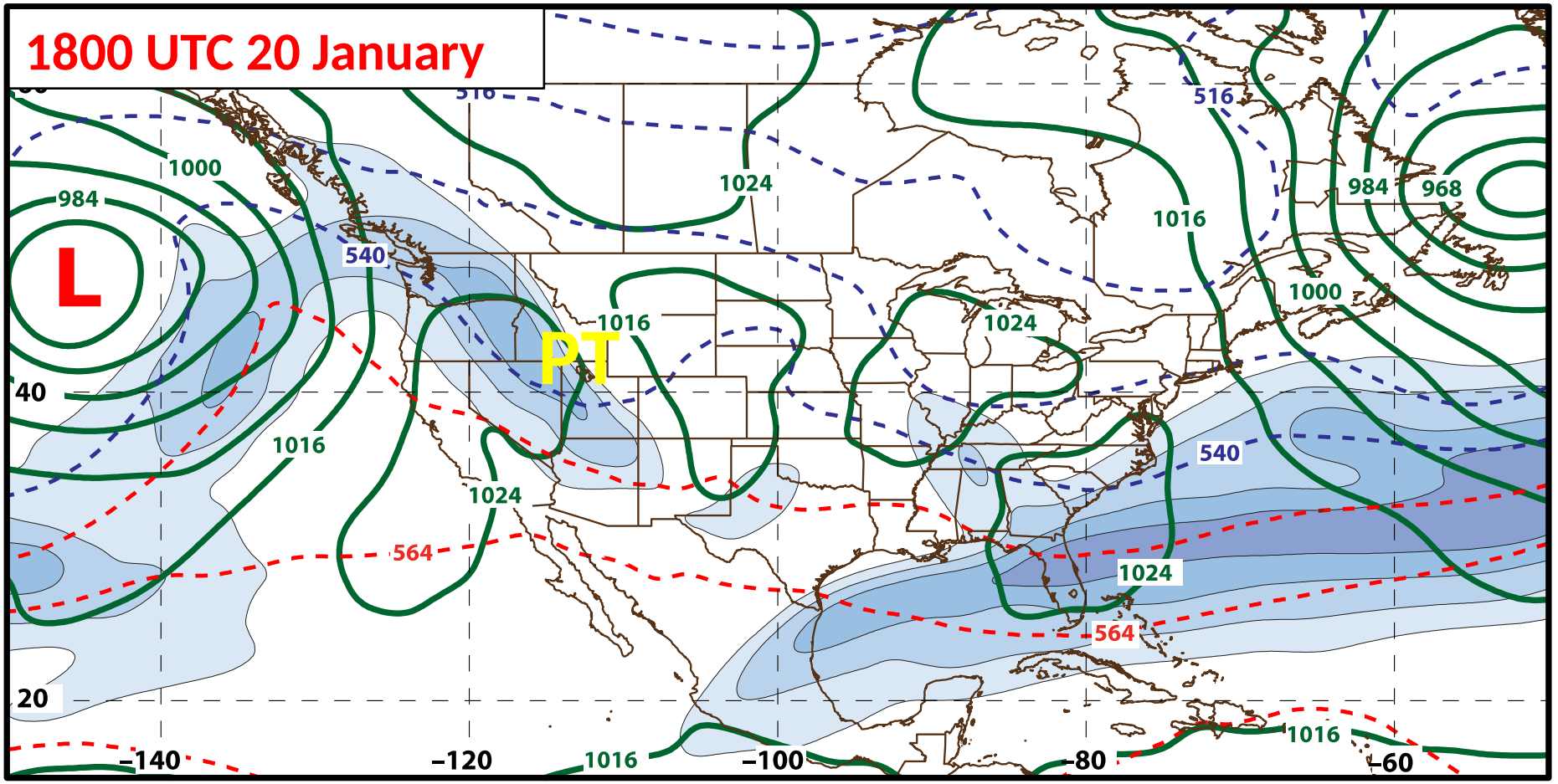


Ending: 0600 UTC 24 January 2016



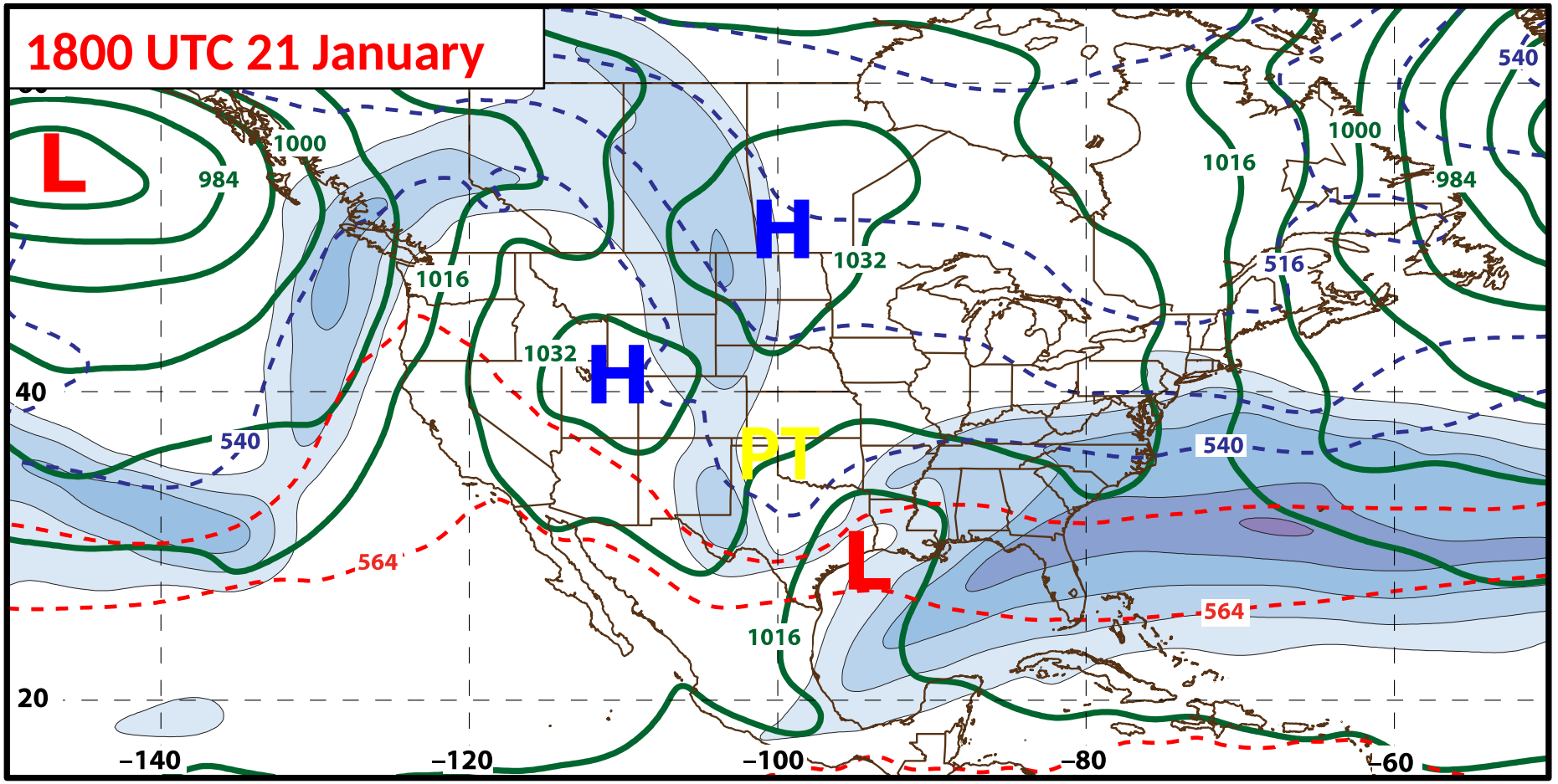
NOHRSC

22–24 January 2016 Blizzard

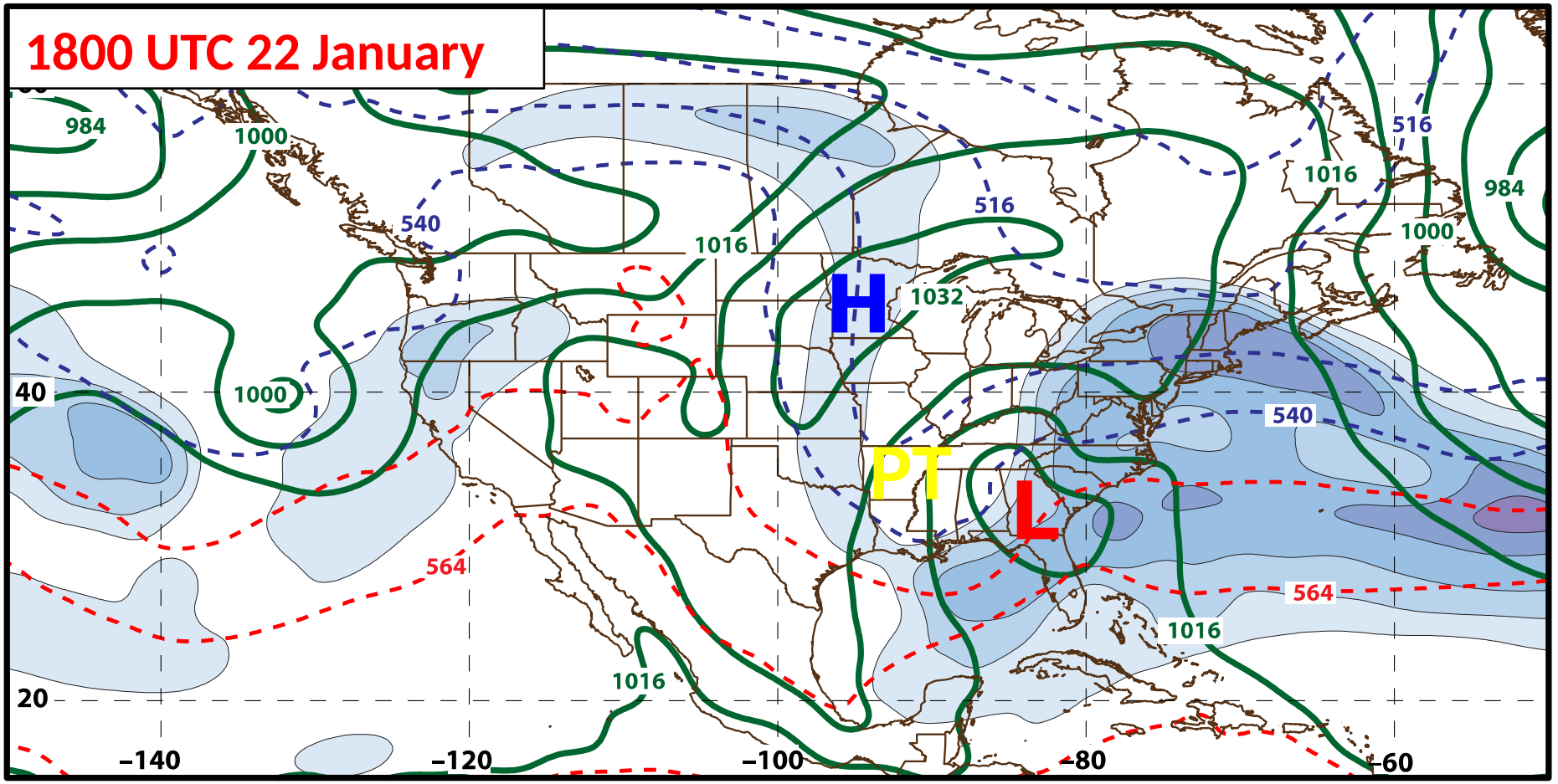


250 hPa Wind Speed (m s^{-1}; fill)
Mean SLP (hPa; green)
1000–500 hPa Thickness (dam; dashed)

22–24 January 2016 Blizzard



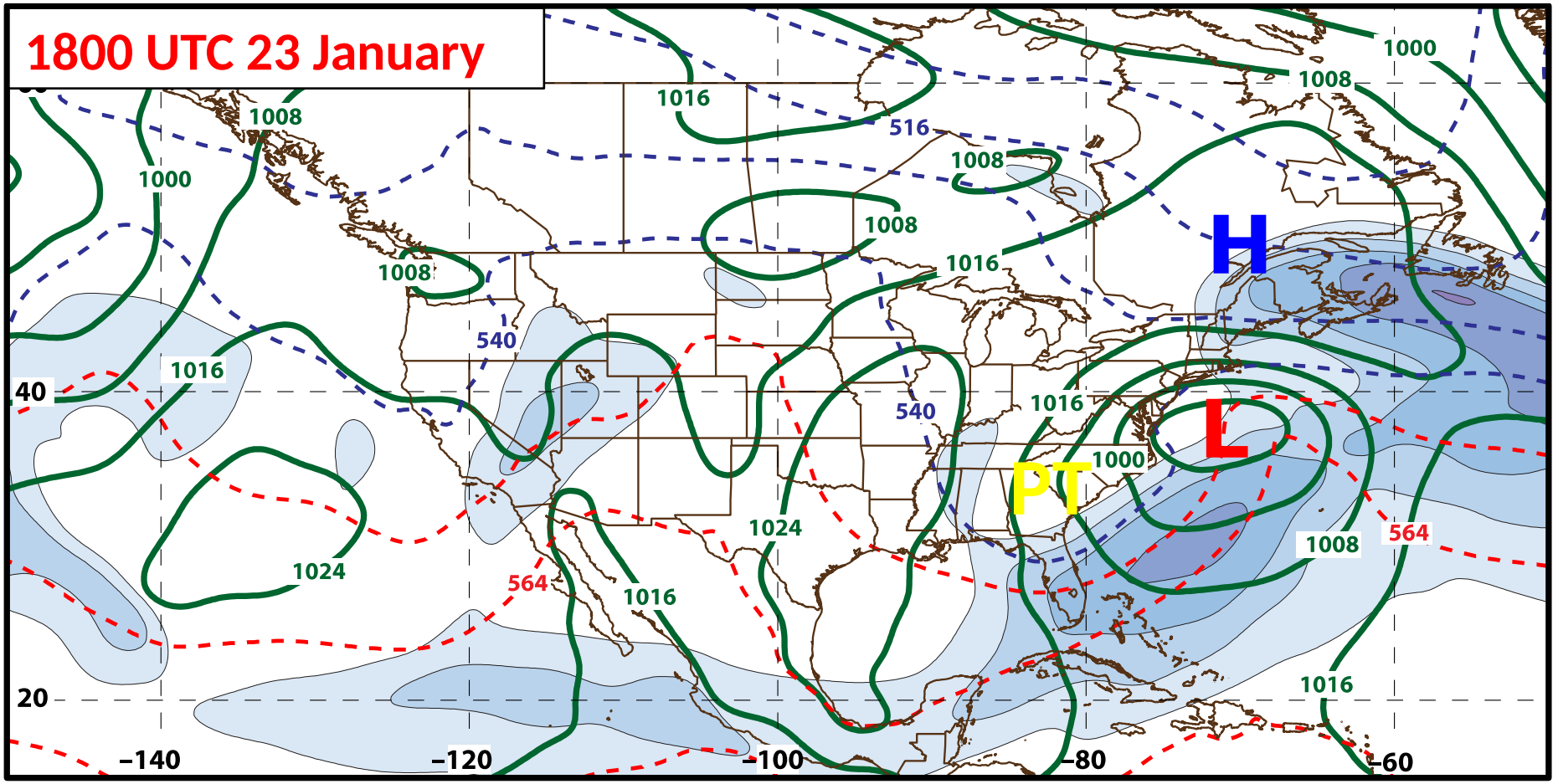
22–24 January 2016 Blizzard



PT = Polar Trough

250 hPa Wind Speed (m s^{-1}; fill)
Mean SLP (hPa; green)
1000–500 hPa Thickness (dam; dashed)

22–24 January 2016 Blizzard



PT = Polar Trough

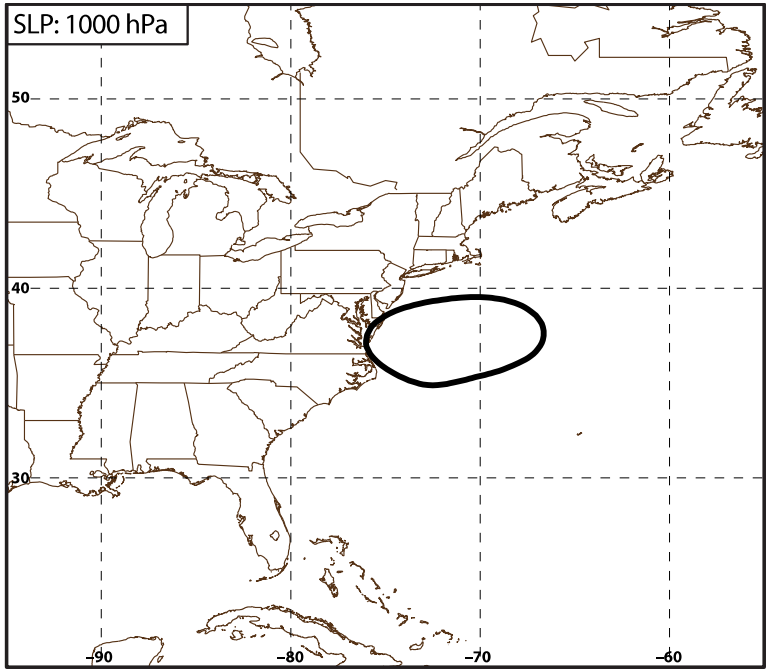
m s^{-1}

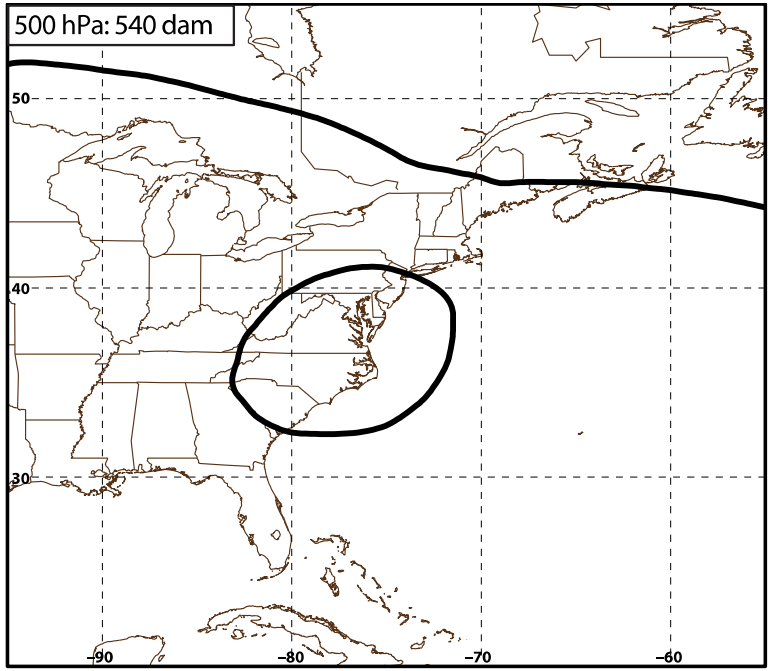
40 50 60 70 80 90 100 110 120

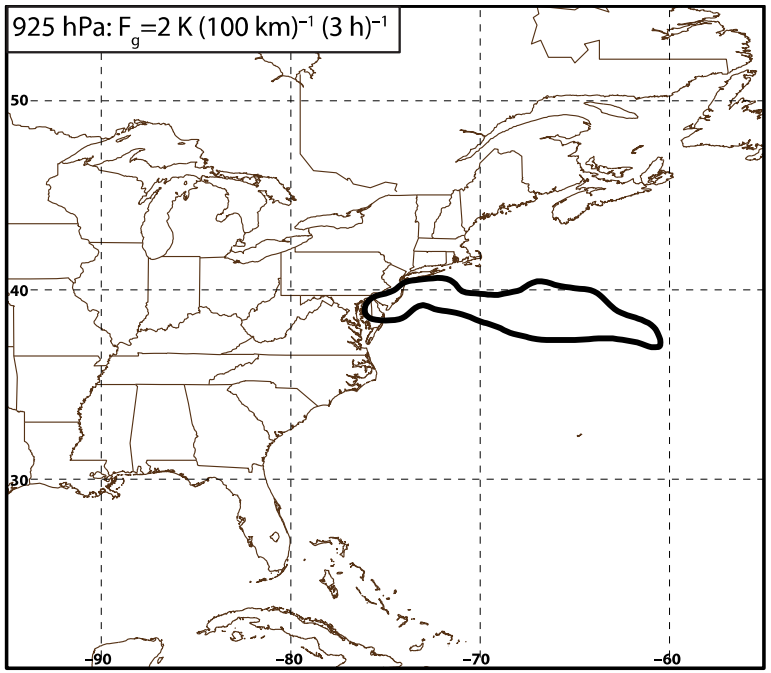
250 hPa Wind Speed (m s^{-1}; fill)
Mean SLP (hPa; green)
1000–500 hPa Thickness (dam; dashed)

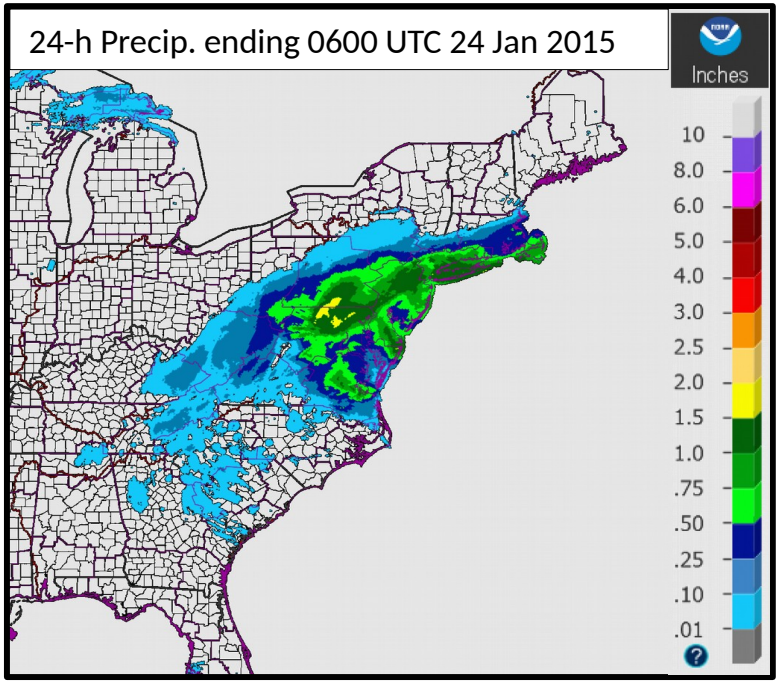
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

00-h





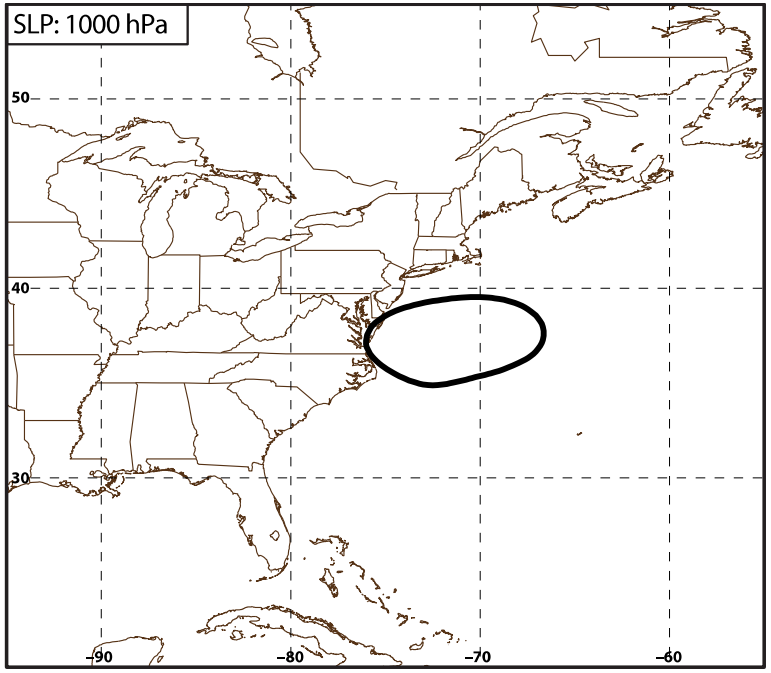


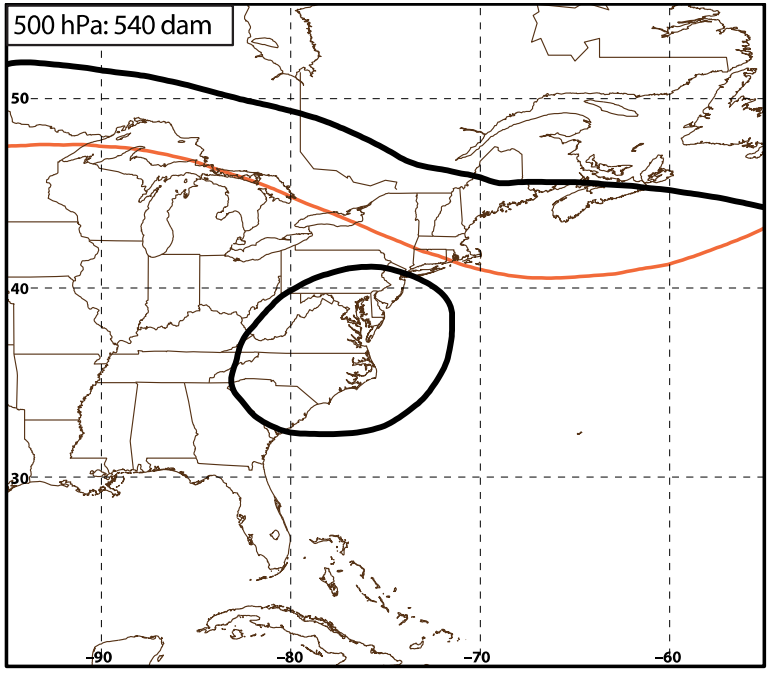


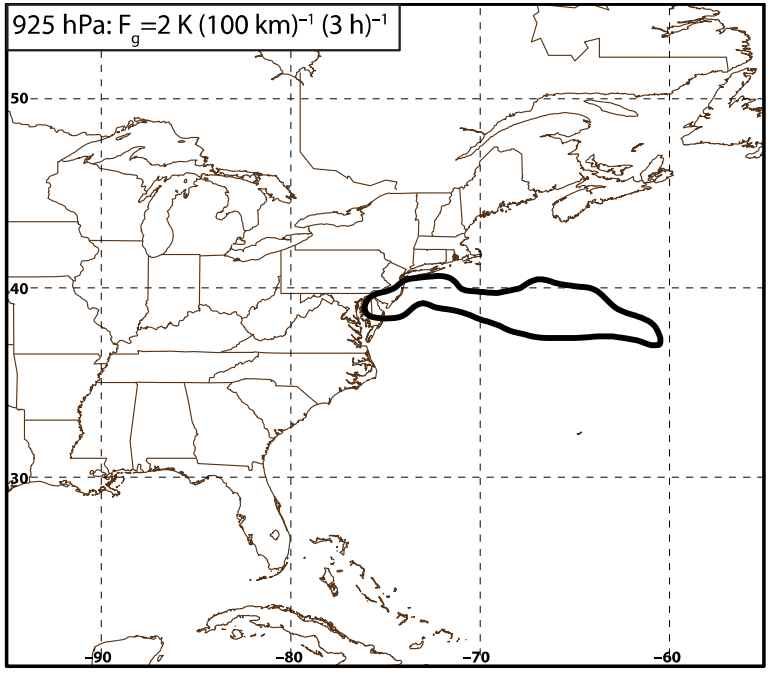
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

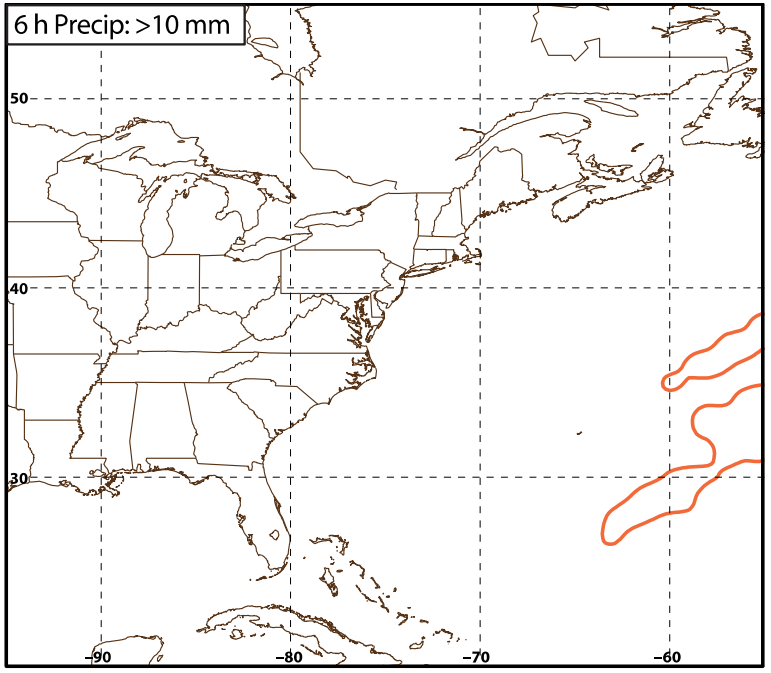
240-h

00-h







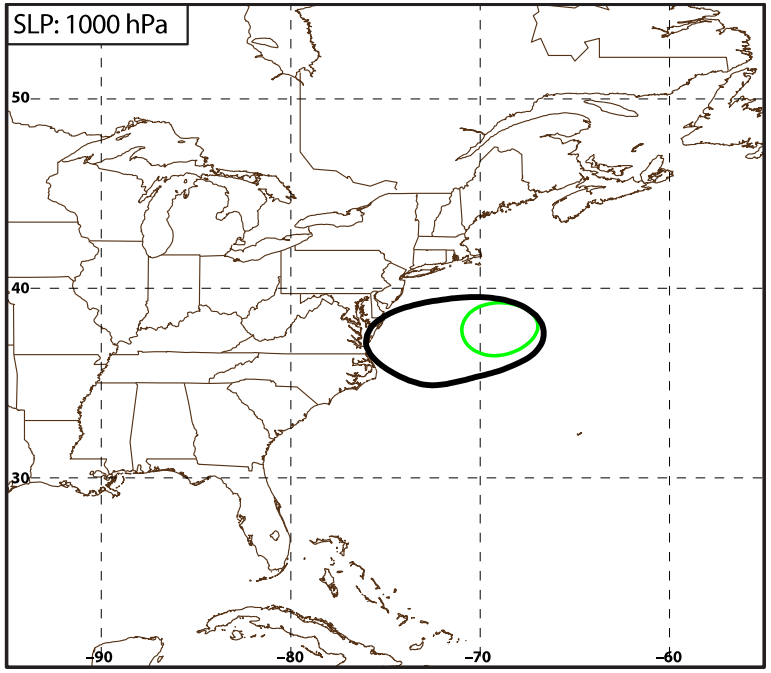


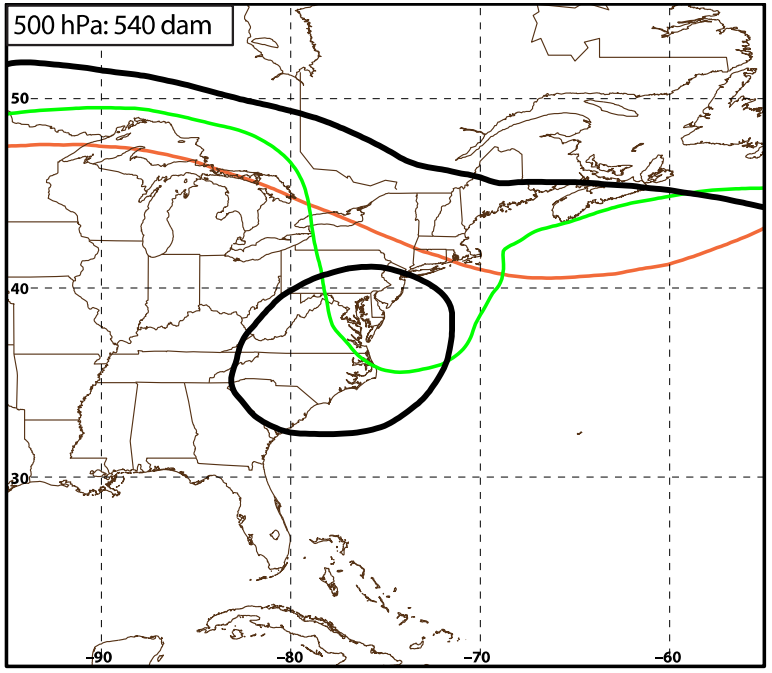
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

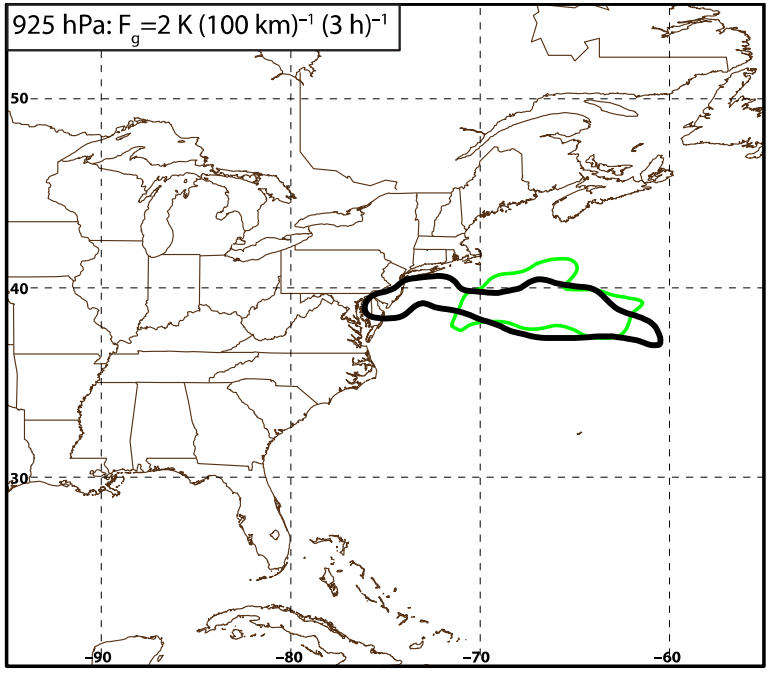
240-h

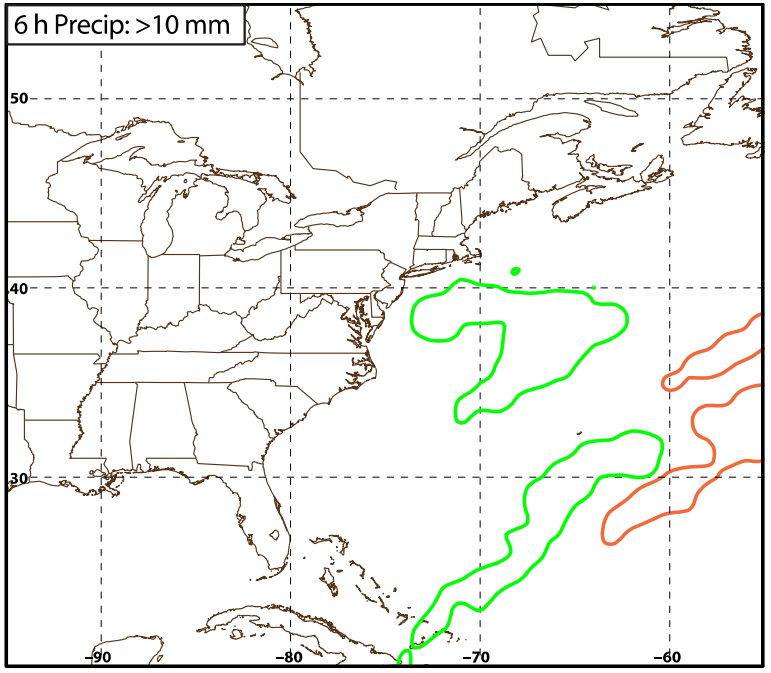
216-h

00-h



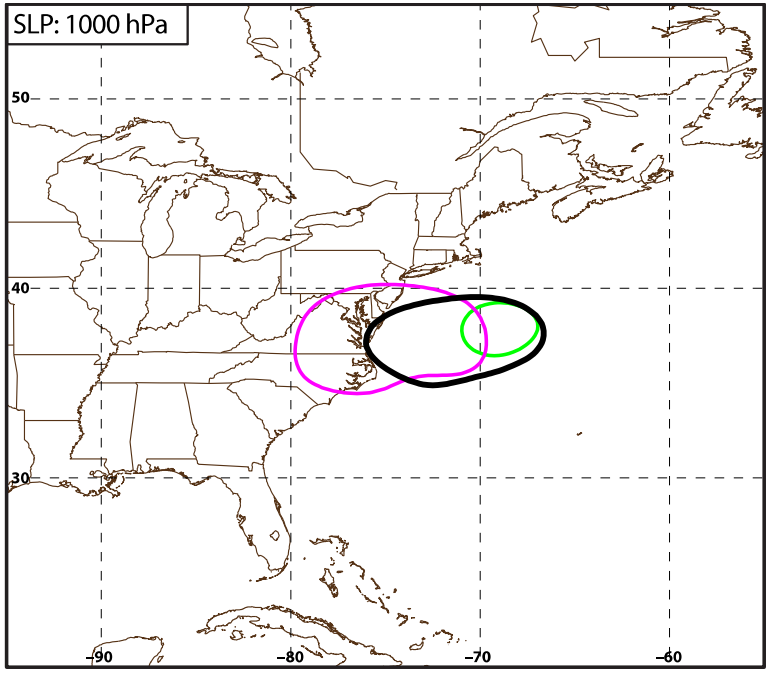


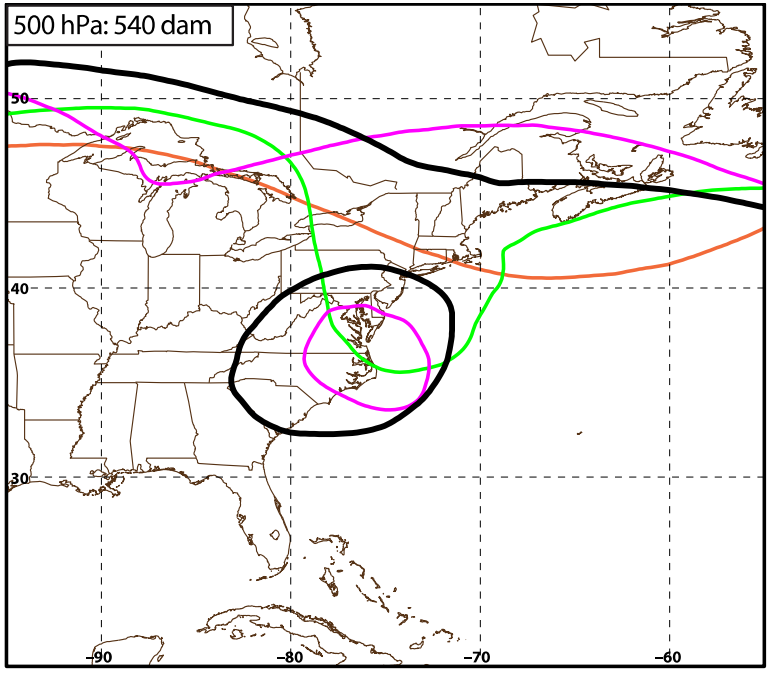


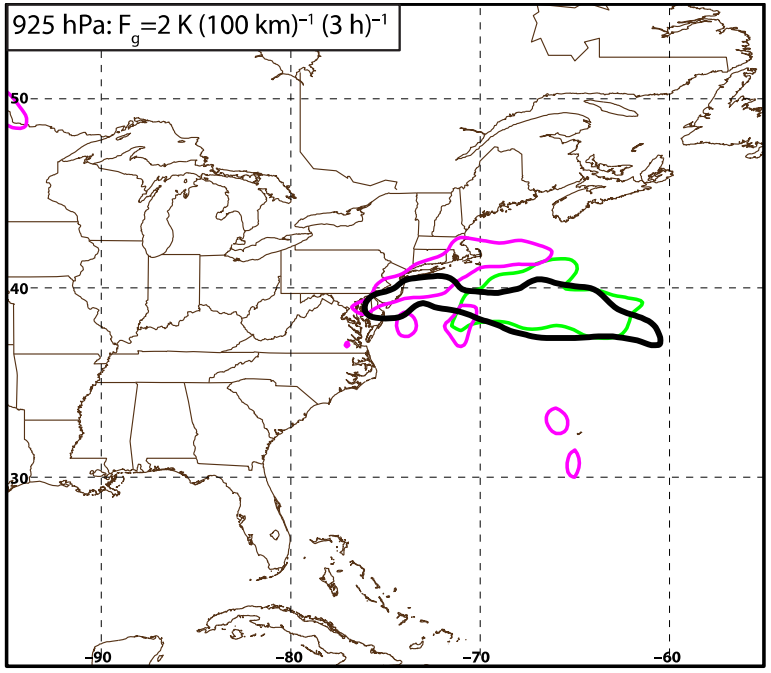


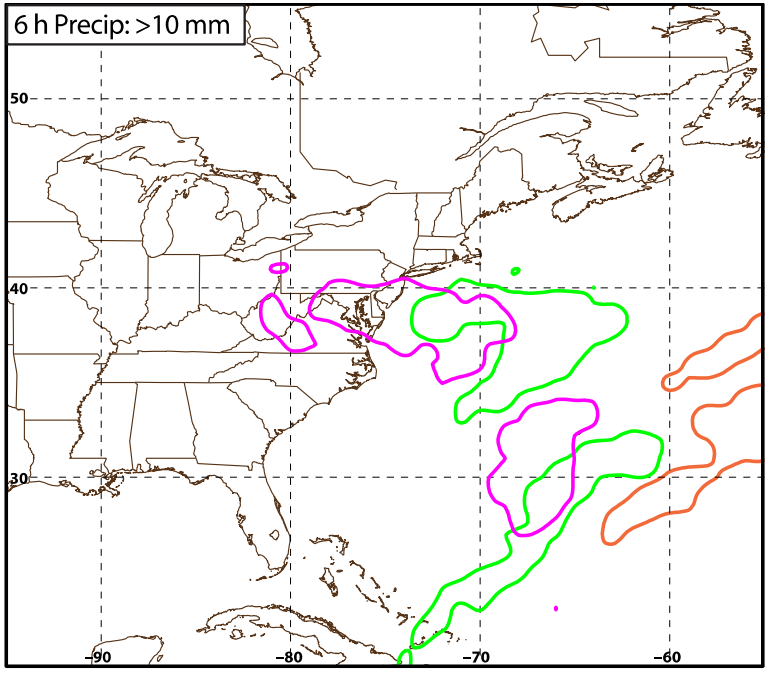
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
00-h



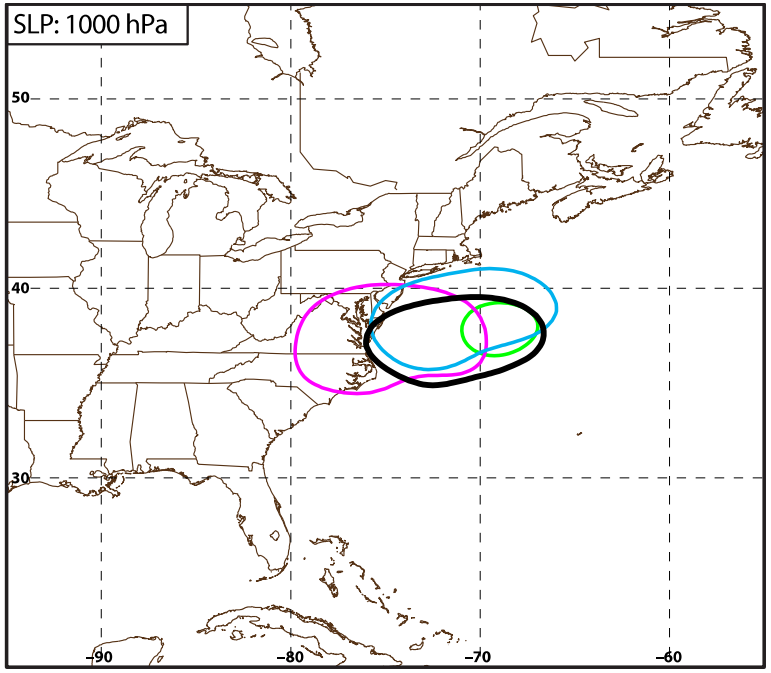


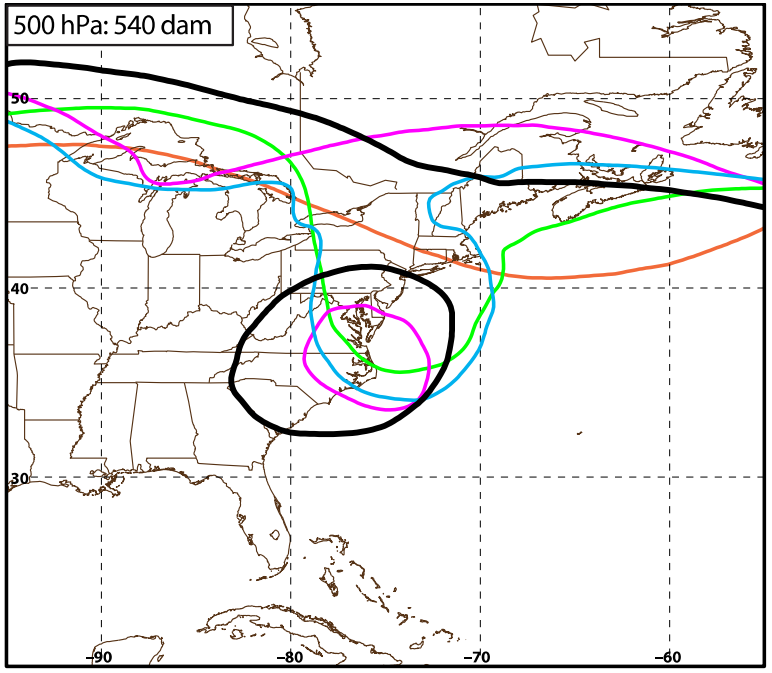


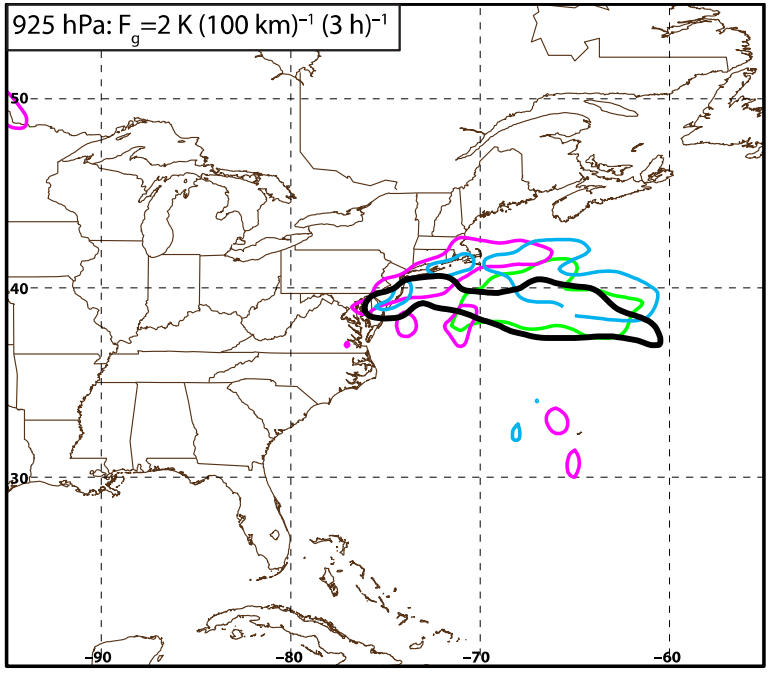


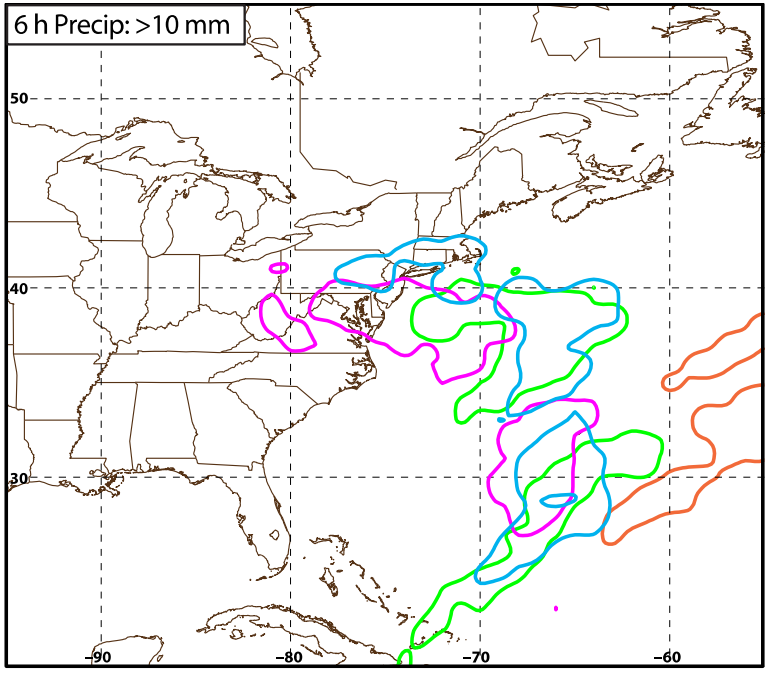
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
00-h



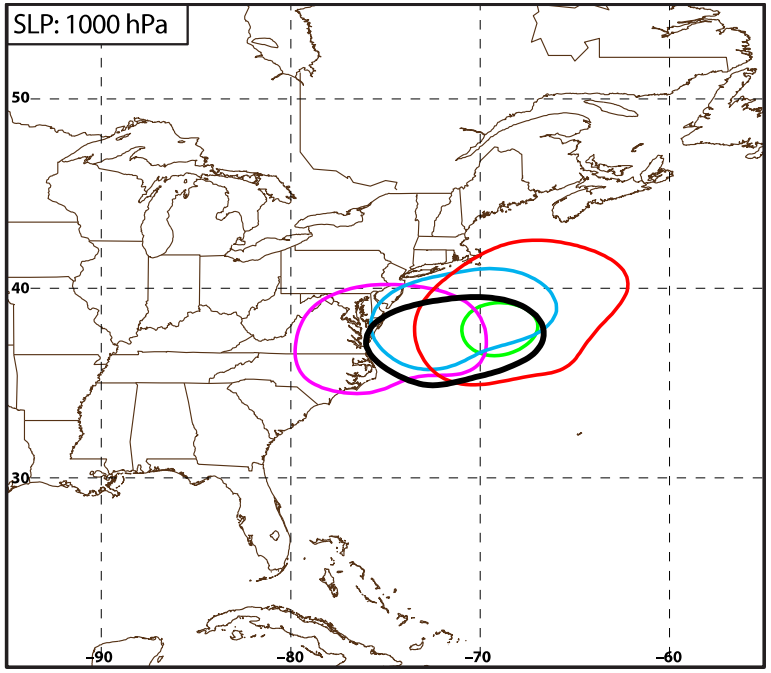


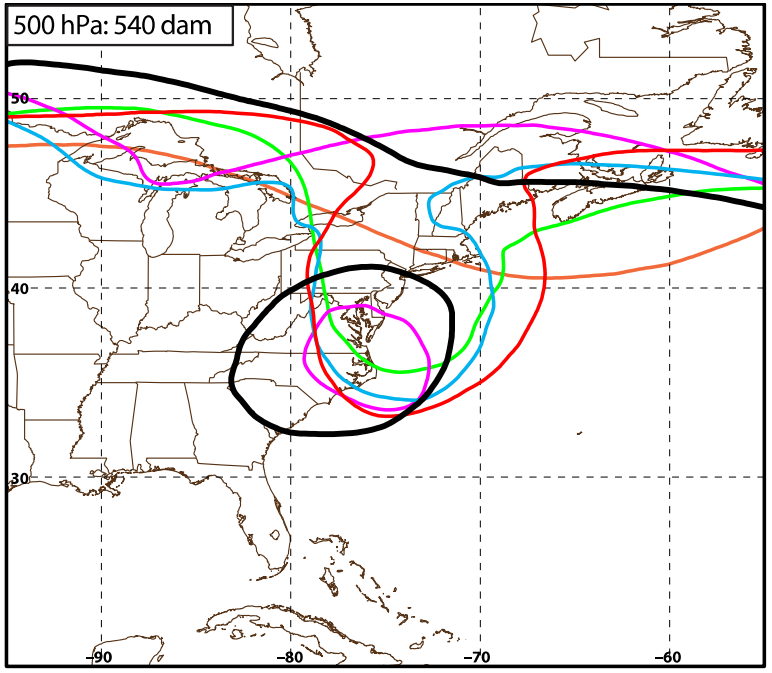


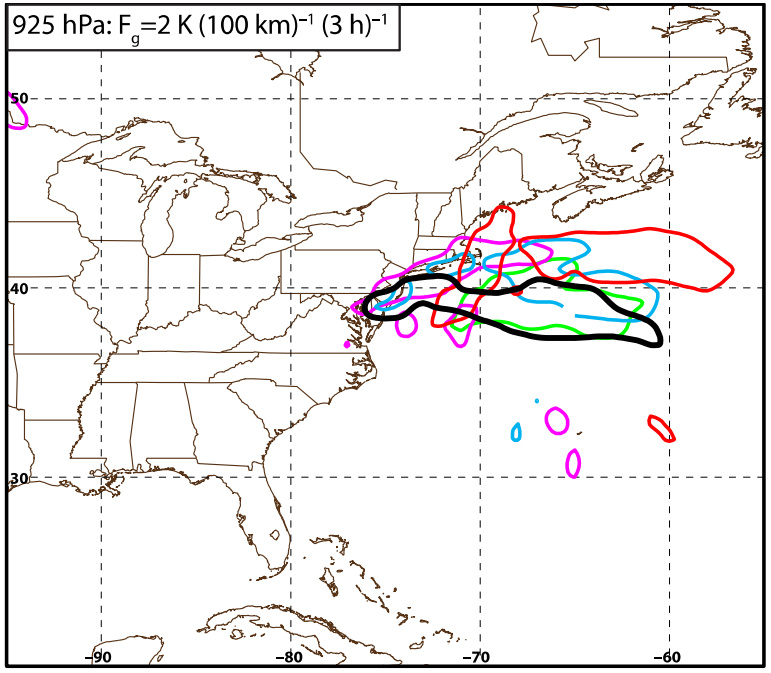


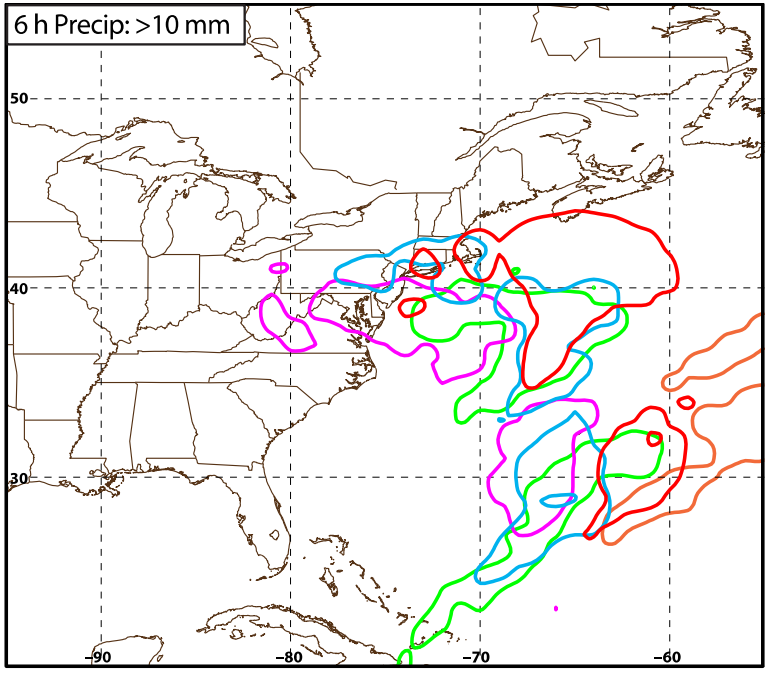
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
00-h



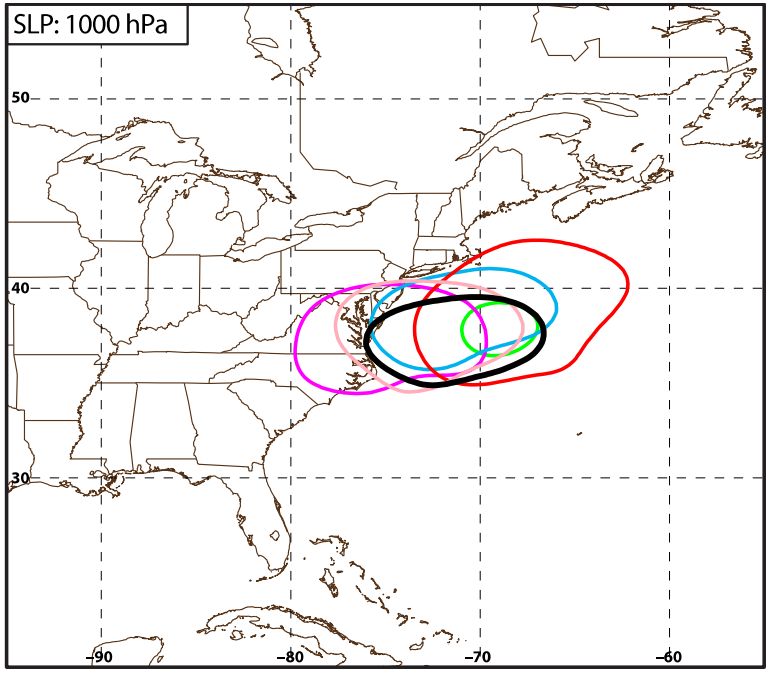


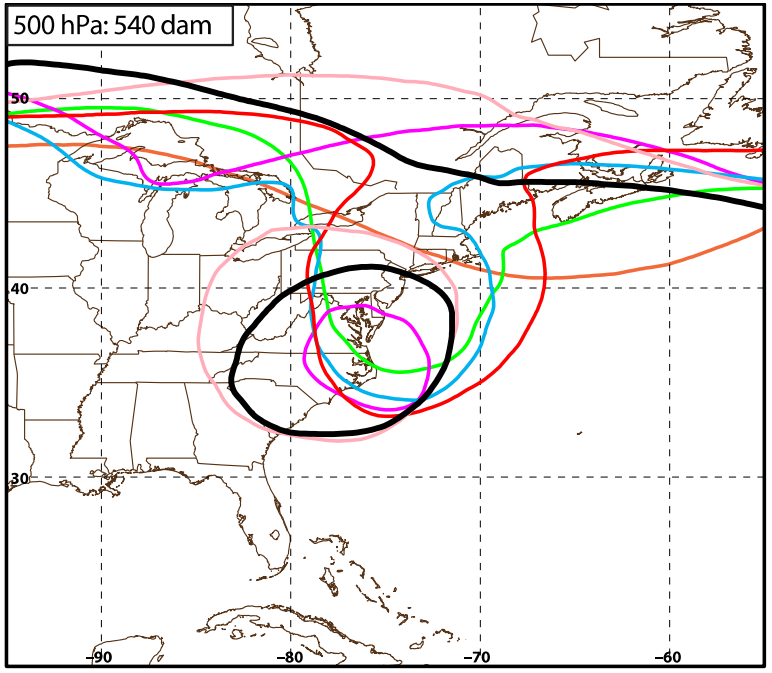


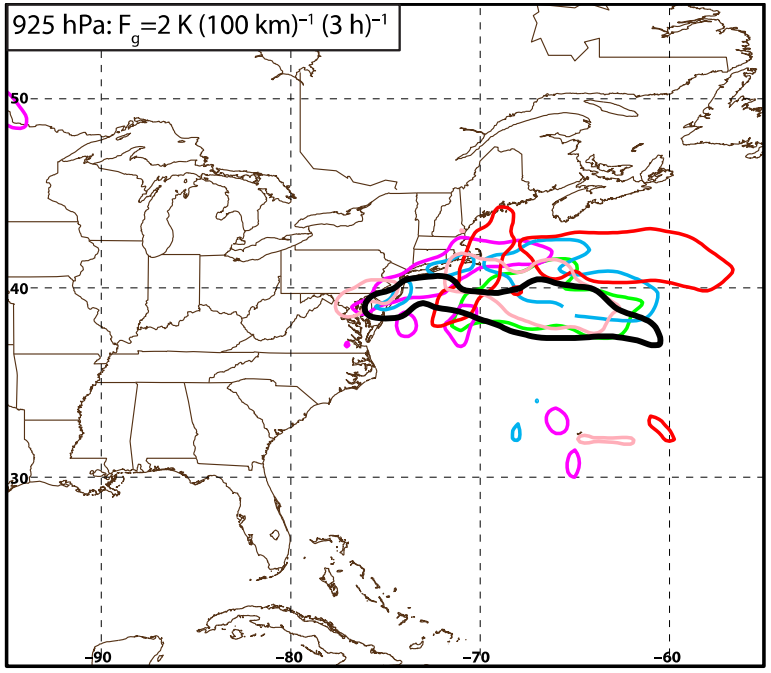


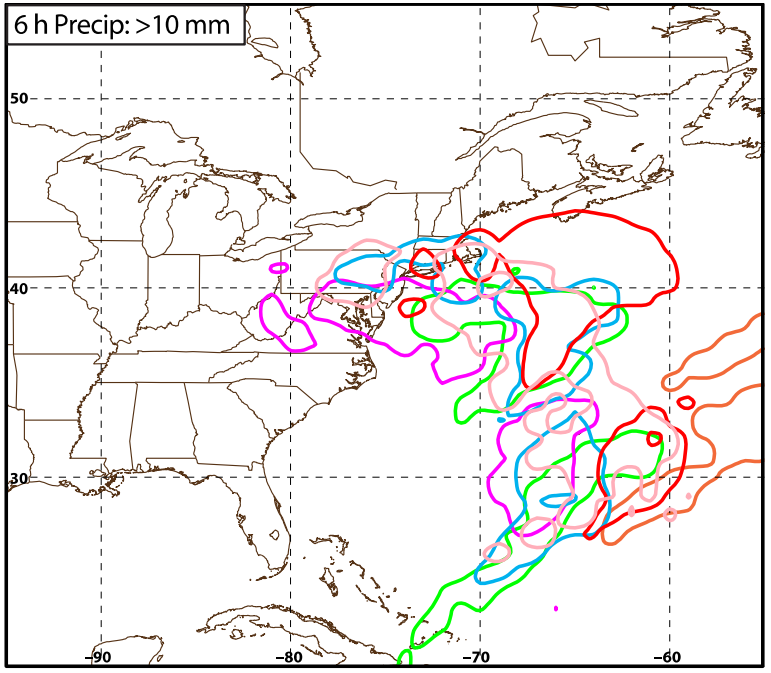
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
120-h
00-h



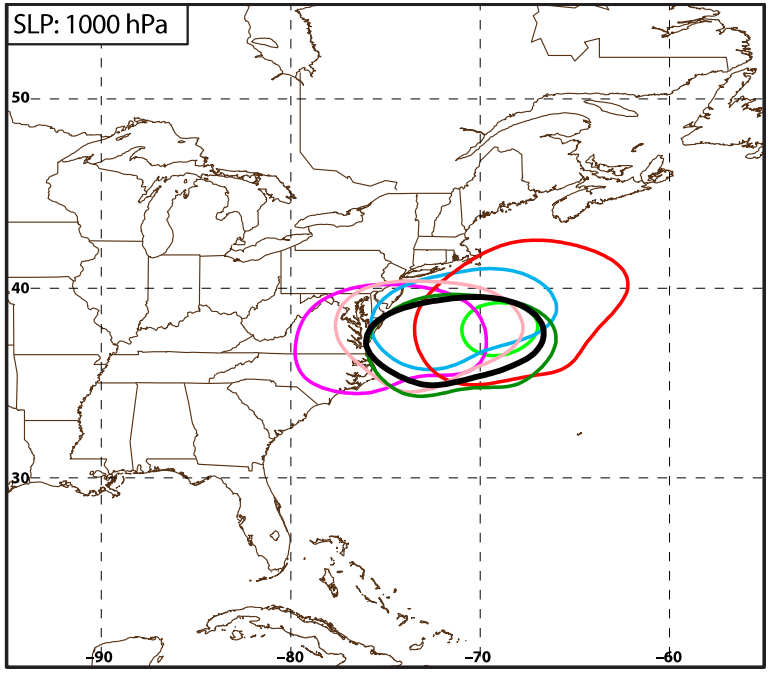


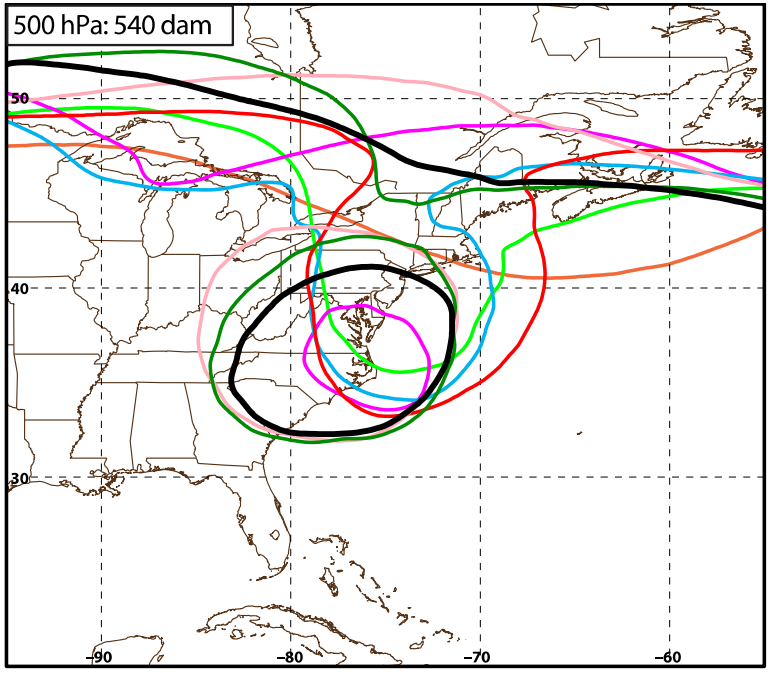


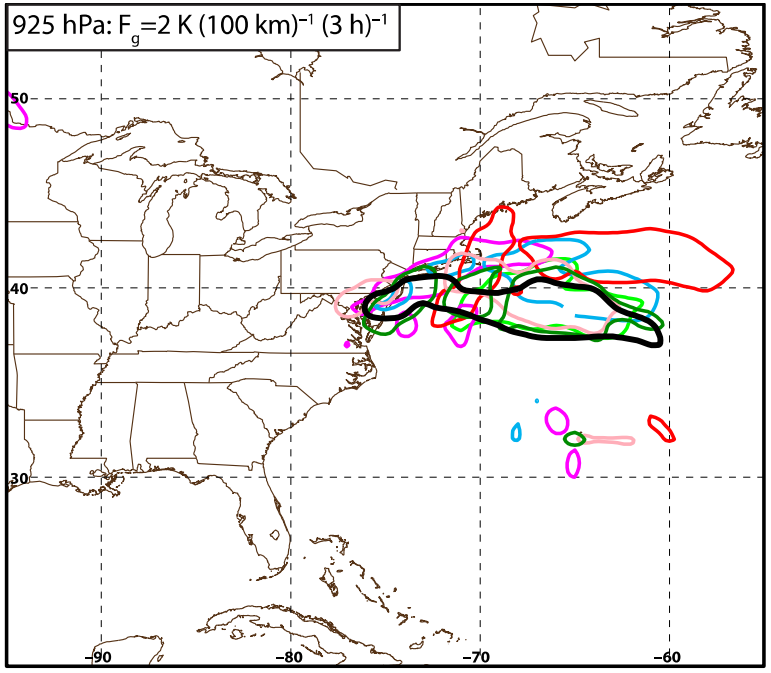


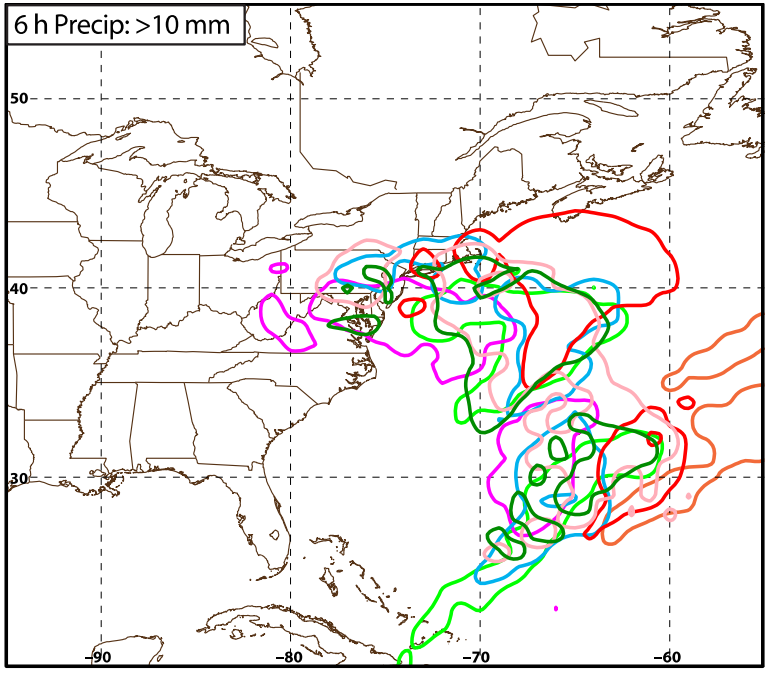
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
120-h
96-h
00-h



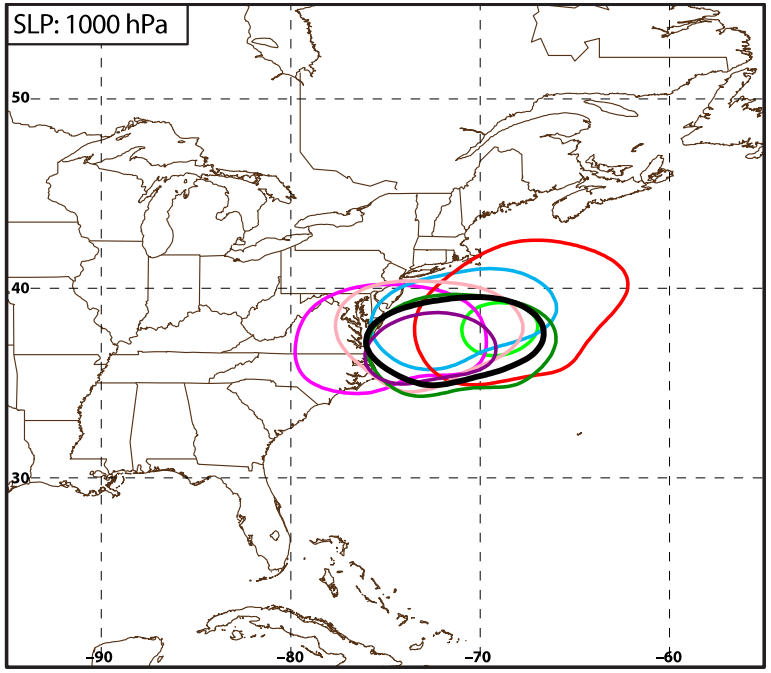


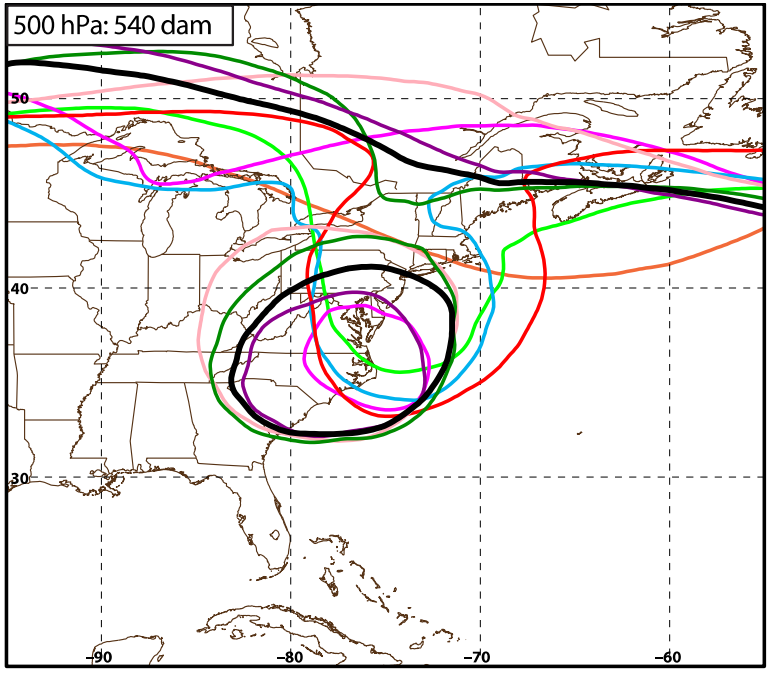


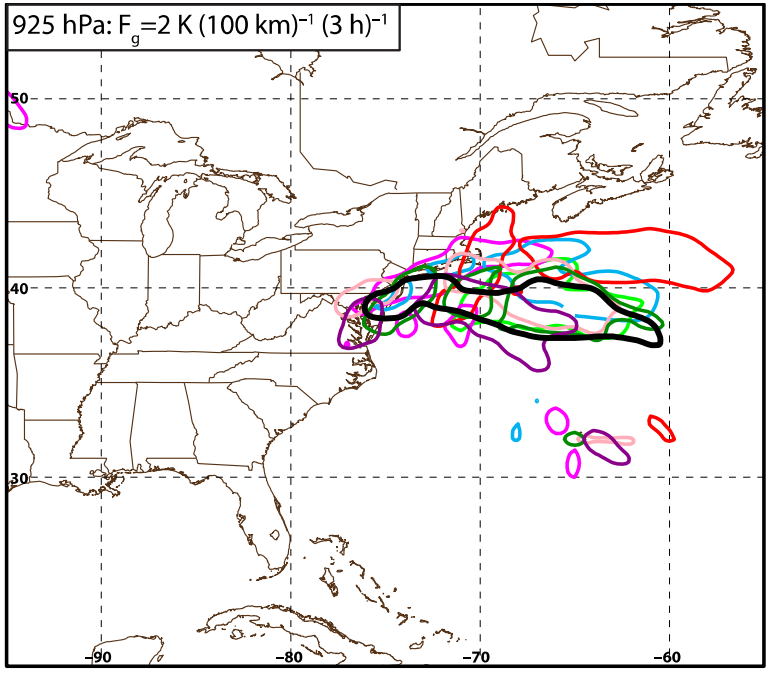


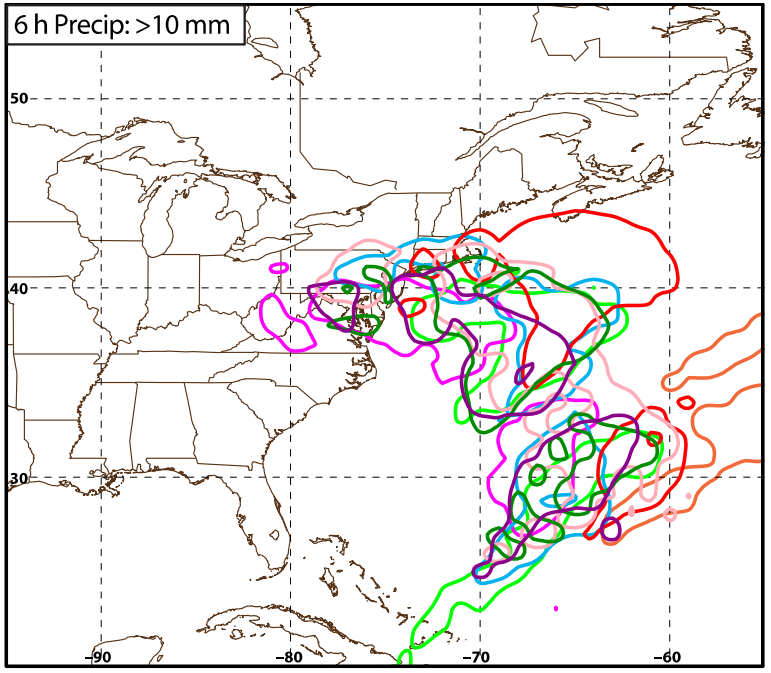
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
120-h
96-h
72-h
00-h



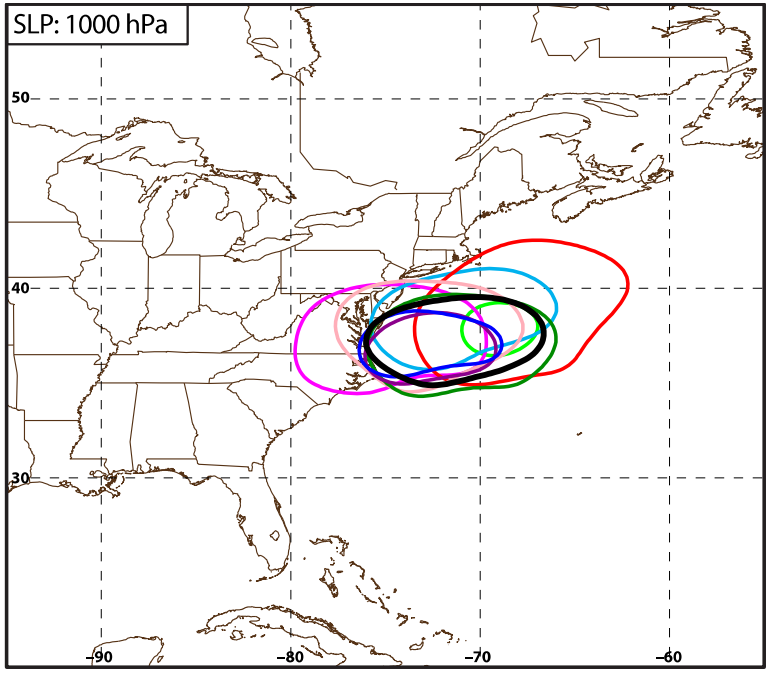


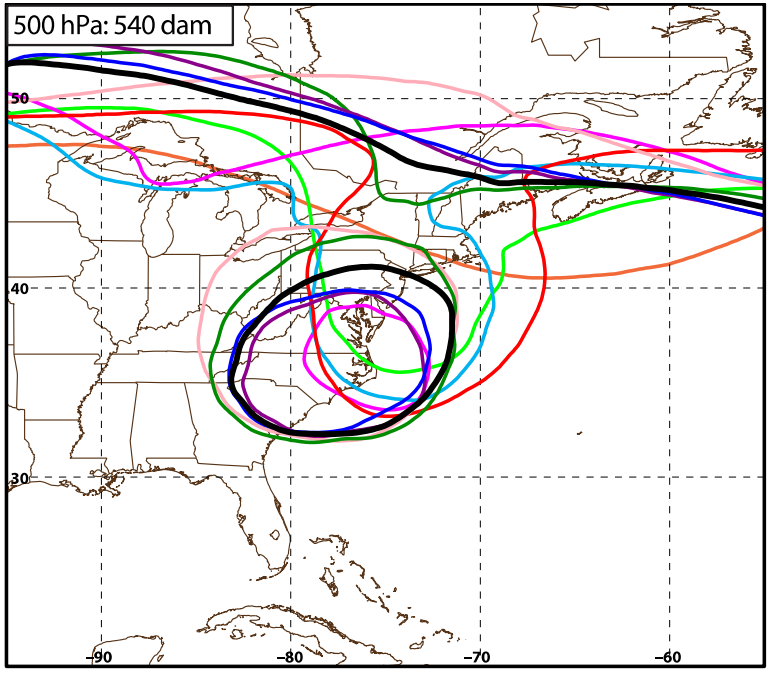


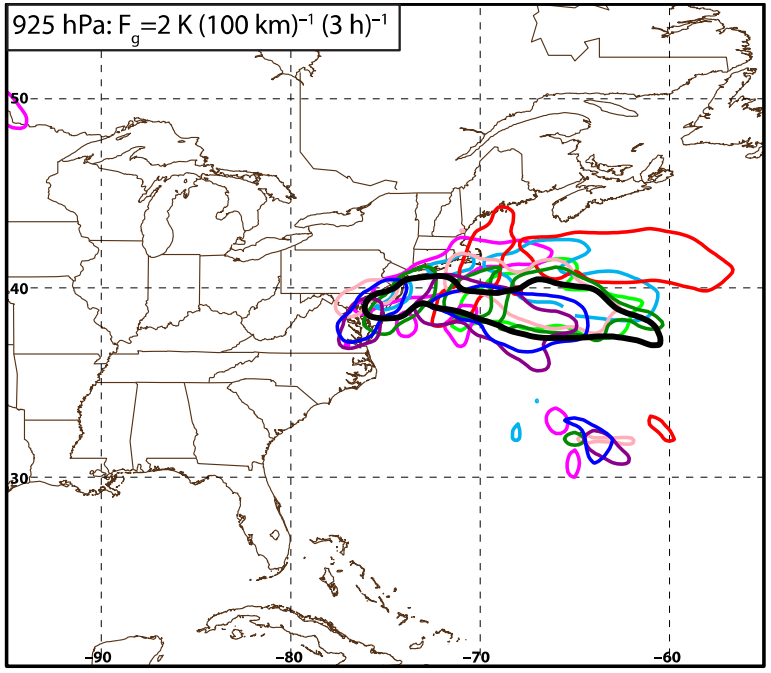


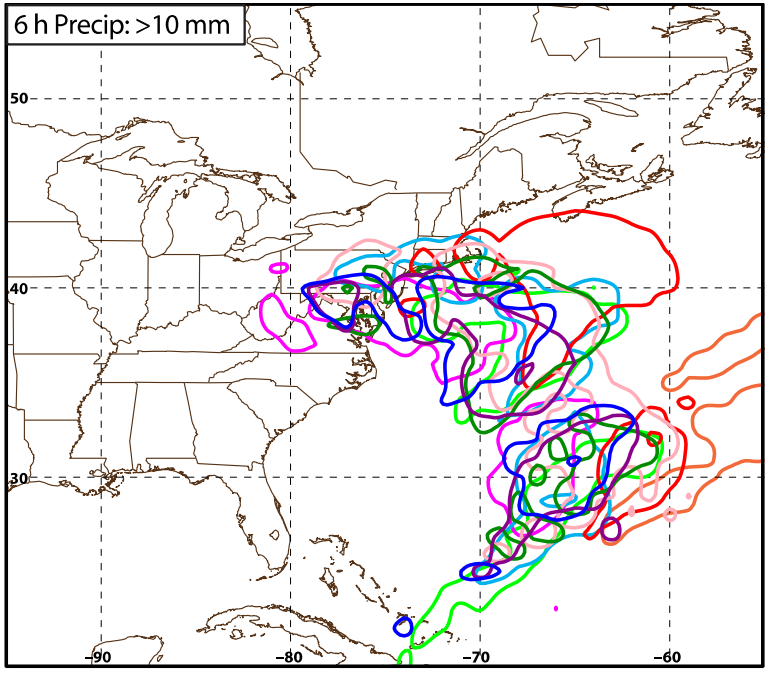
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
120-h
96-h
72-h
48-h
00-h



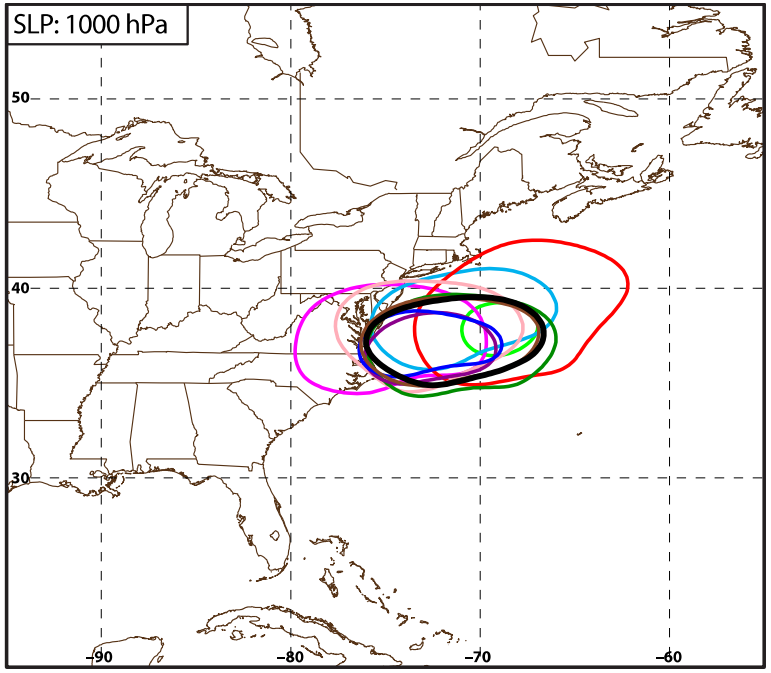


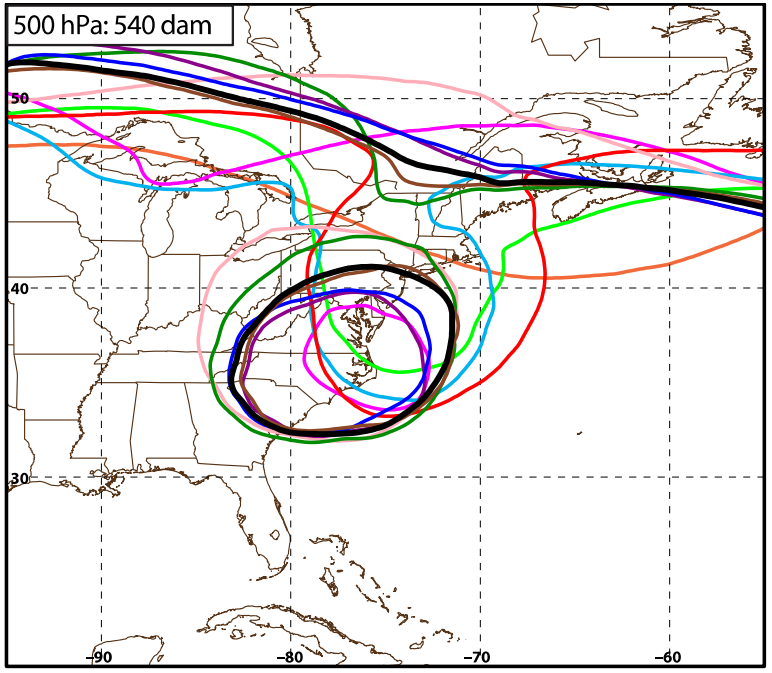


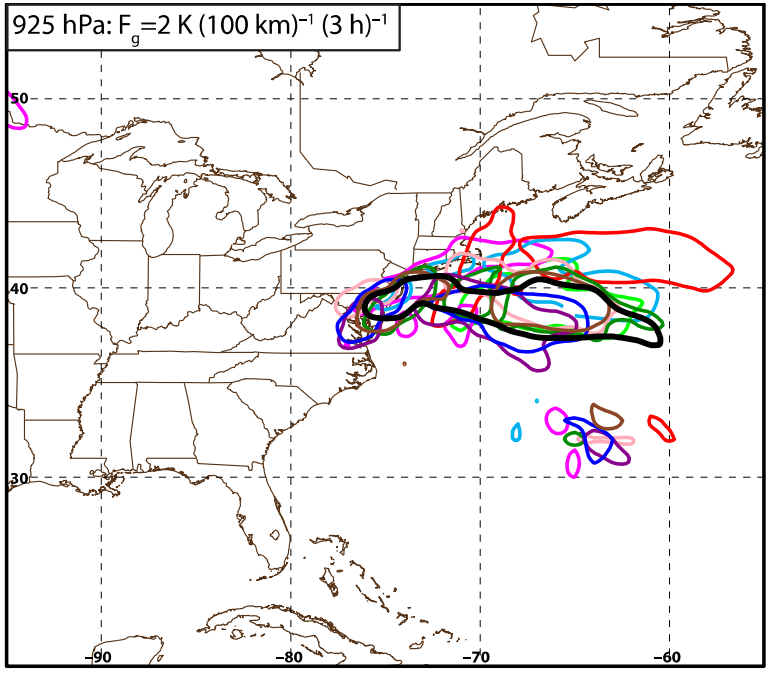


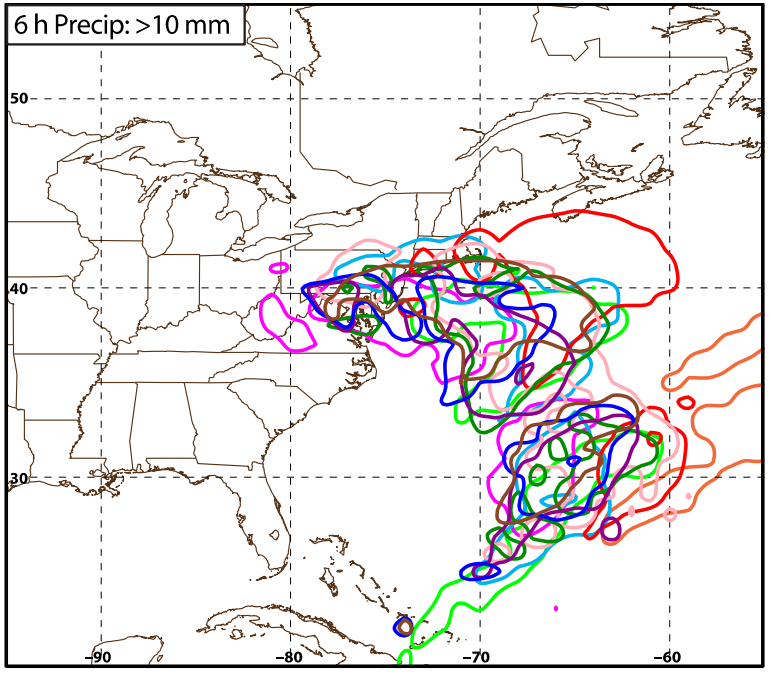
GFS Forecasts Verifying 1800 UTC 23 Jan 2016

240-h
216-h
192-h
168-h
144-h
120-h
96-h
72-h
48-h
24-h
00-h







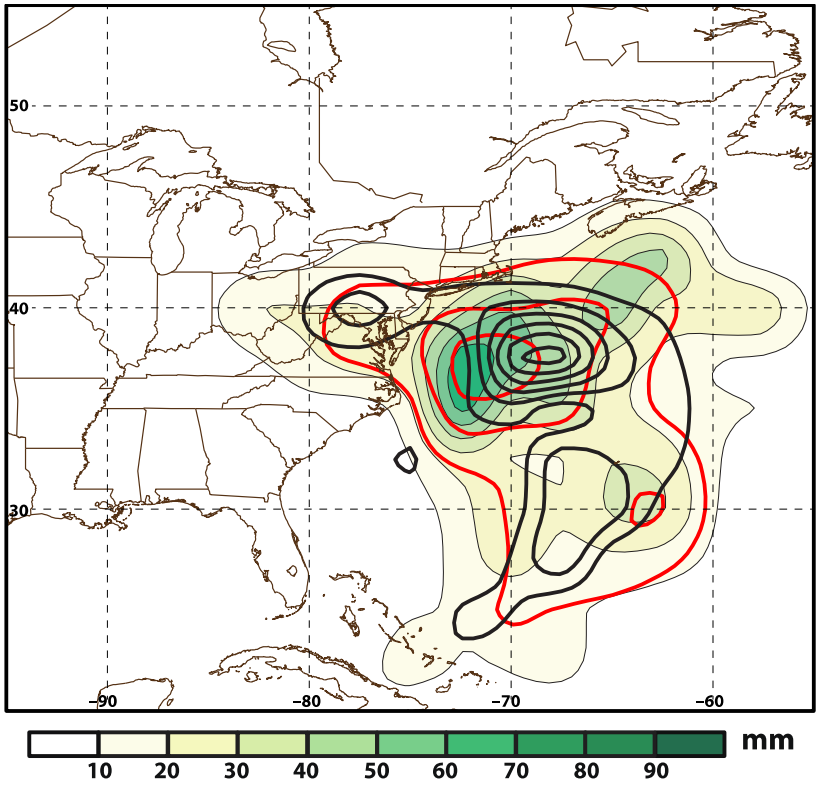


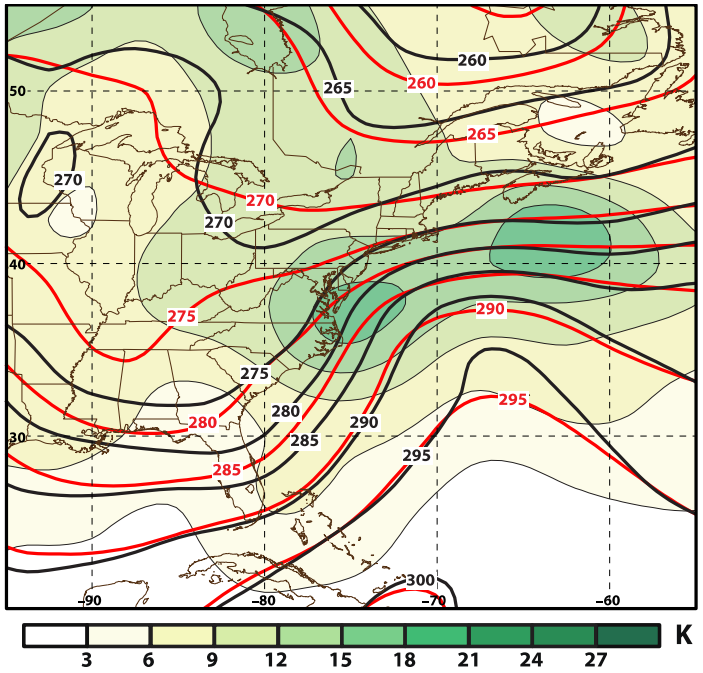
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

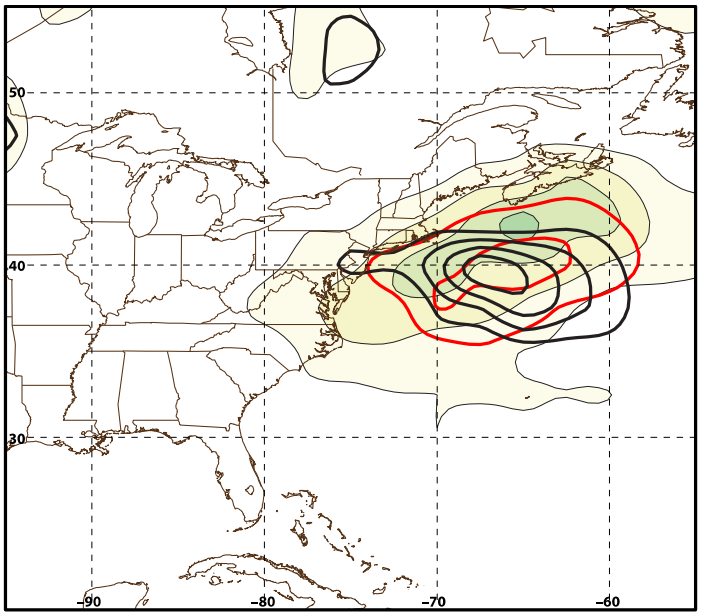
120-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

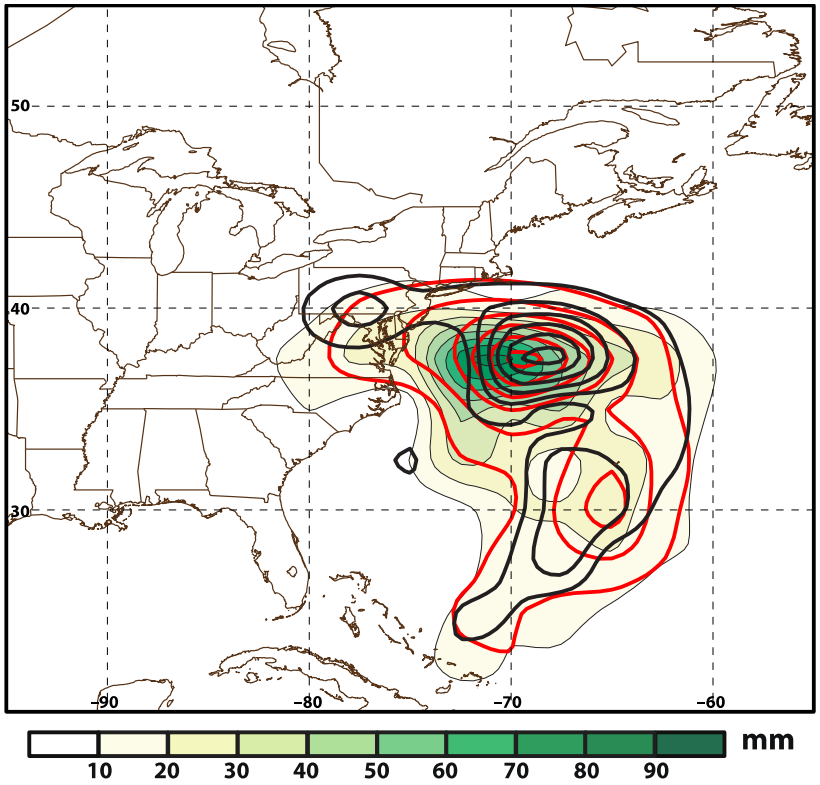
Ens. Mean — Analysis

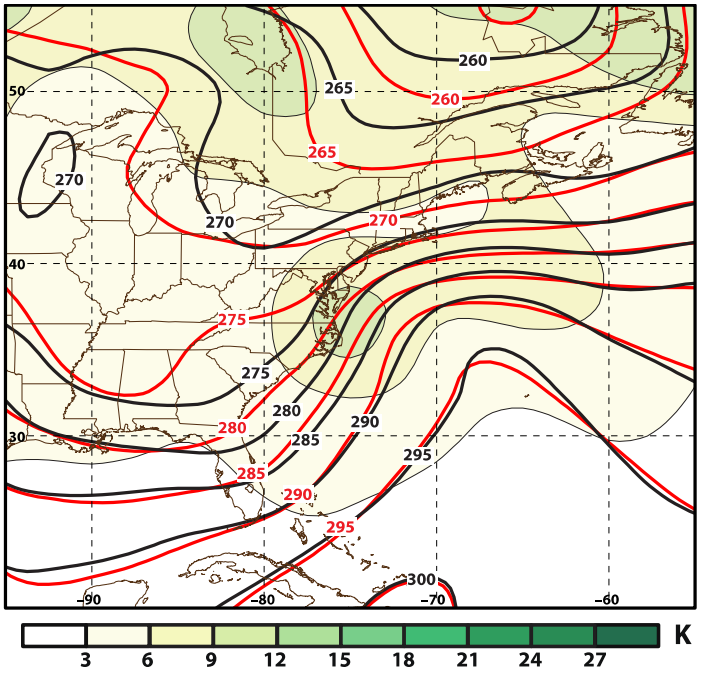
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

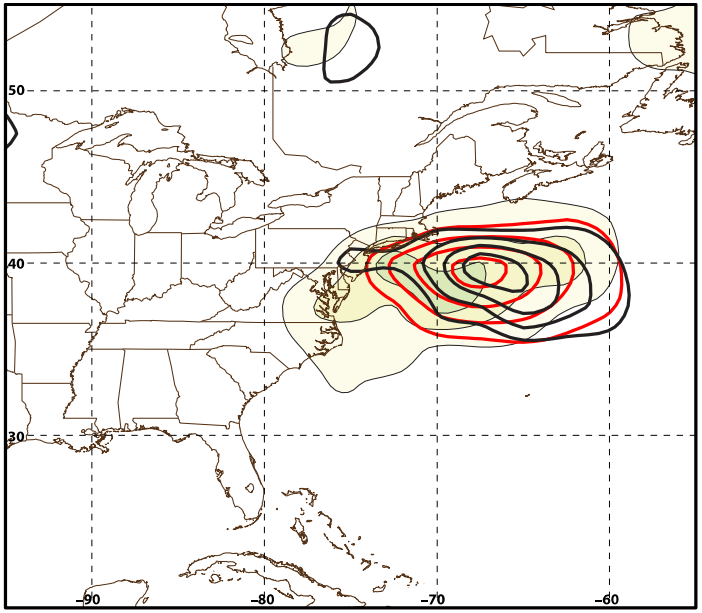
96-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

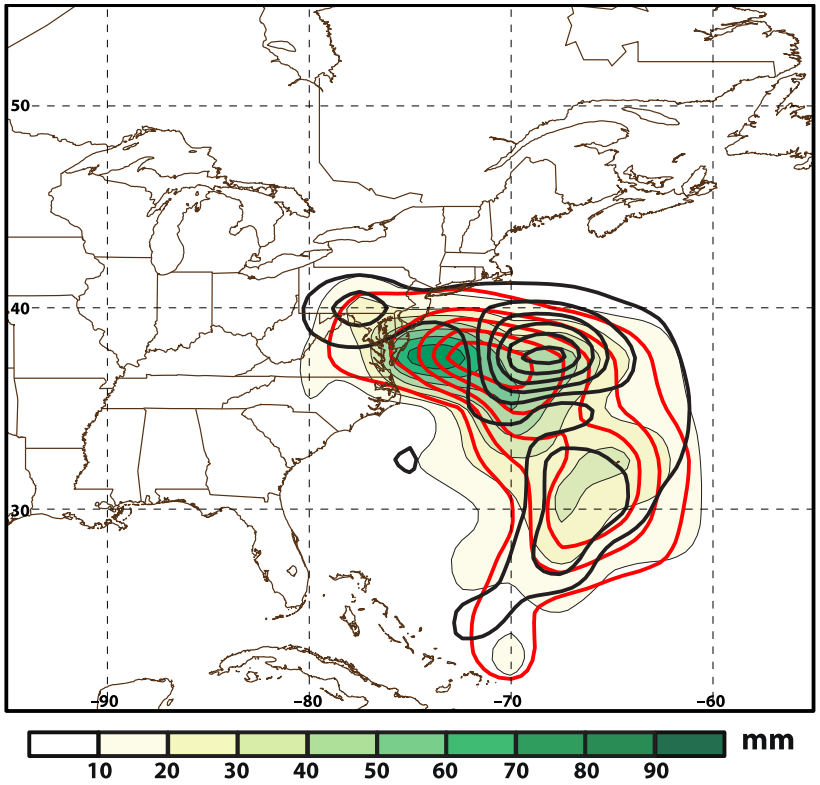
Ens. Mean Analysis

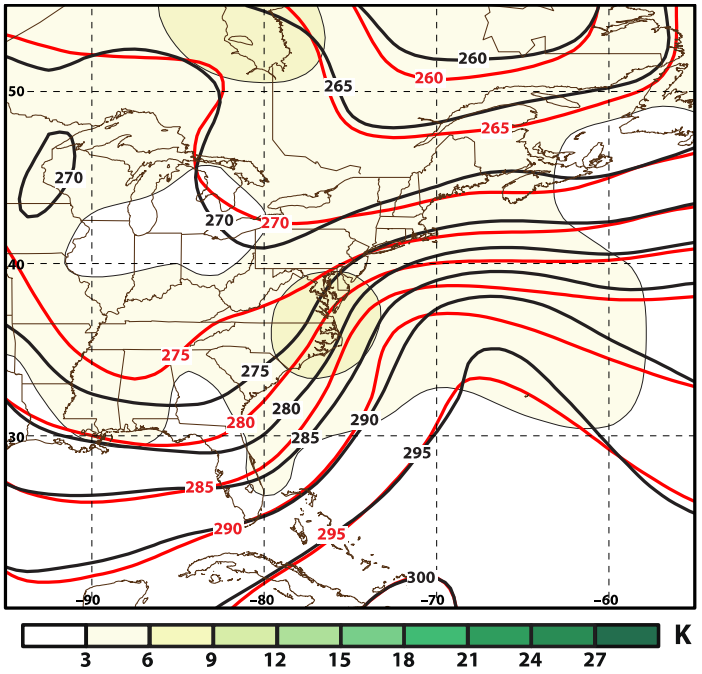
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

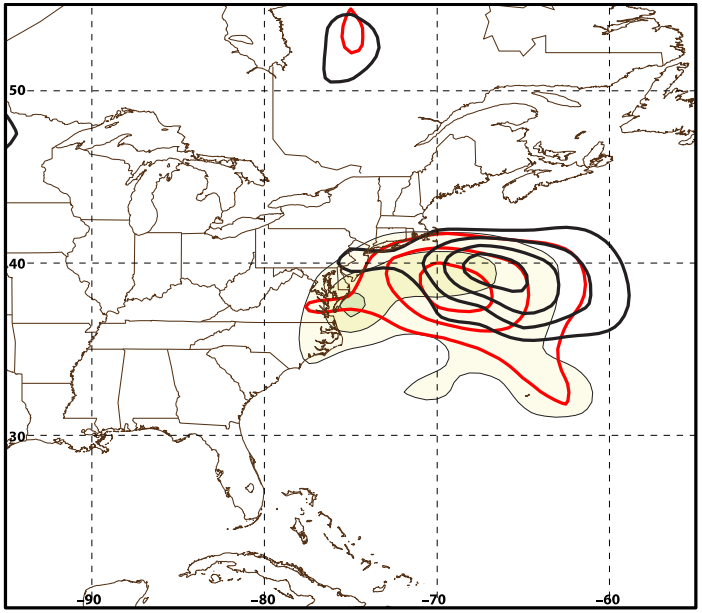
72-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

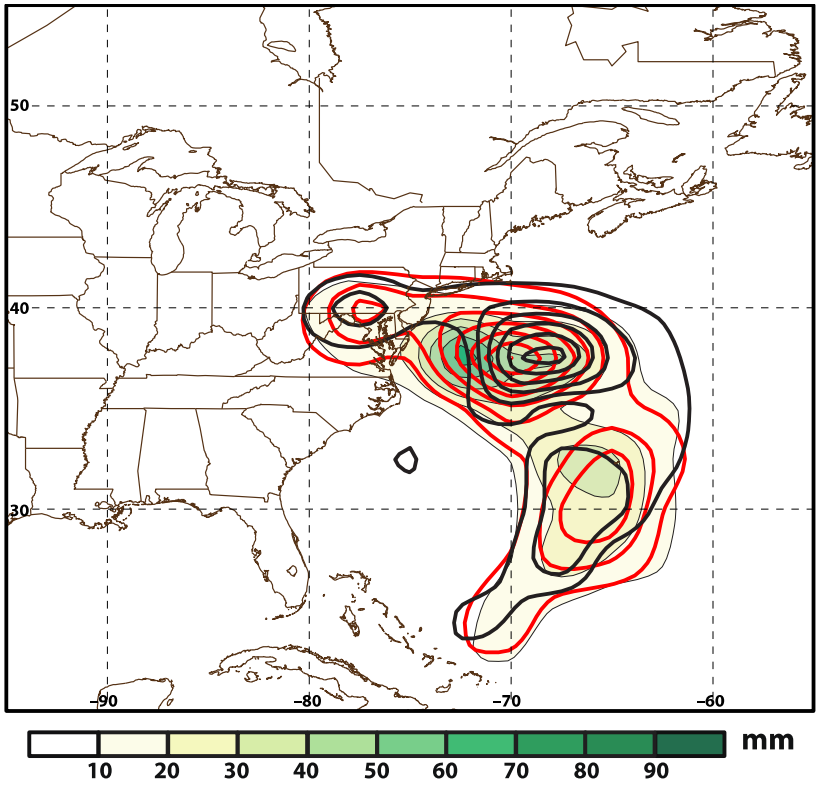
Ens. Mean — Analysis

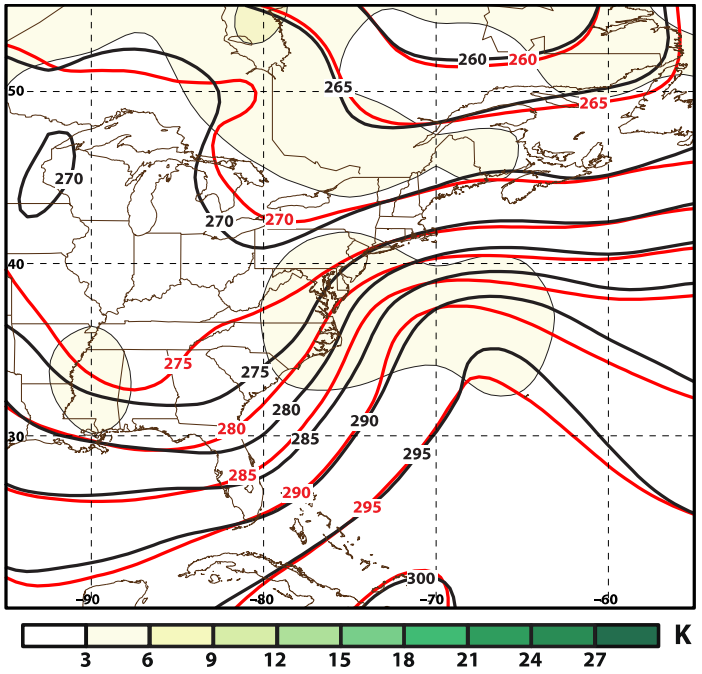
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

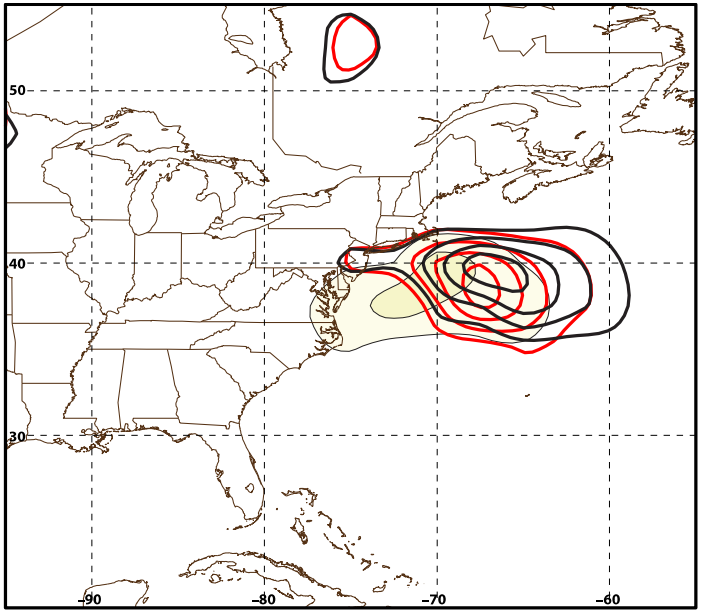
48-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

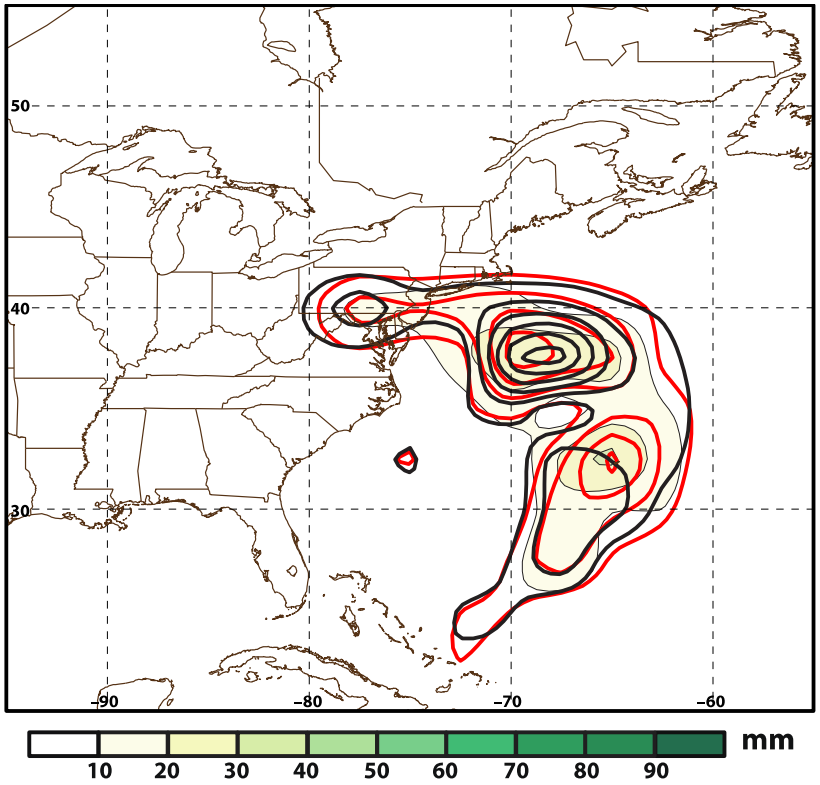
Ens. Mean — Analysis

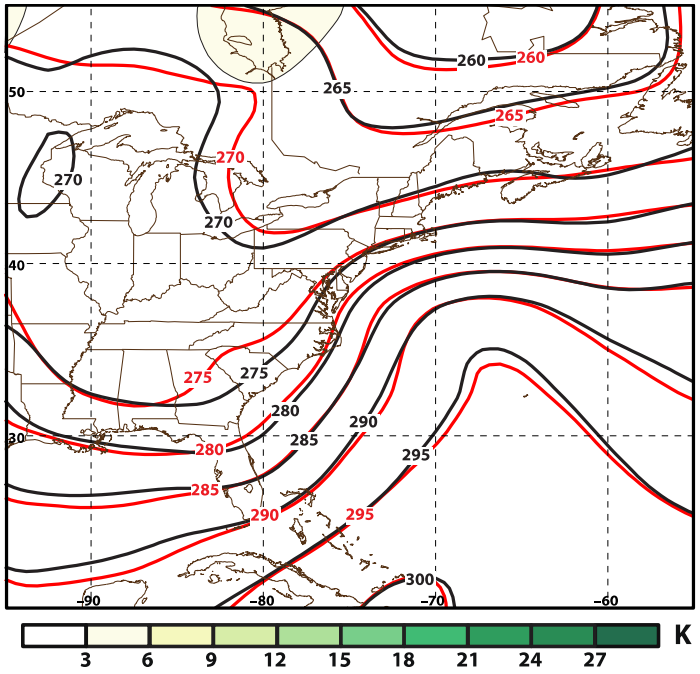
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

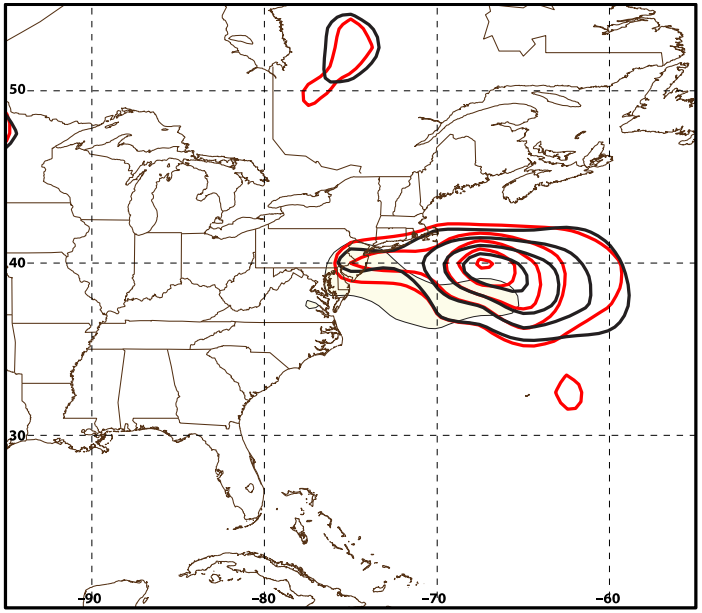
24-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

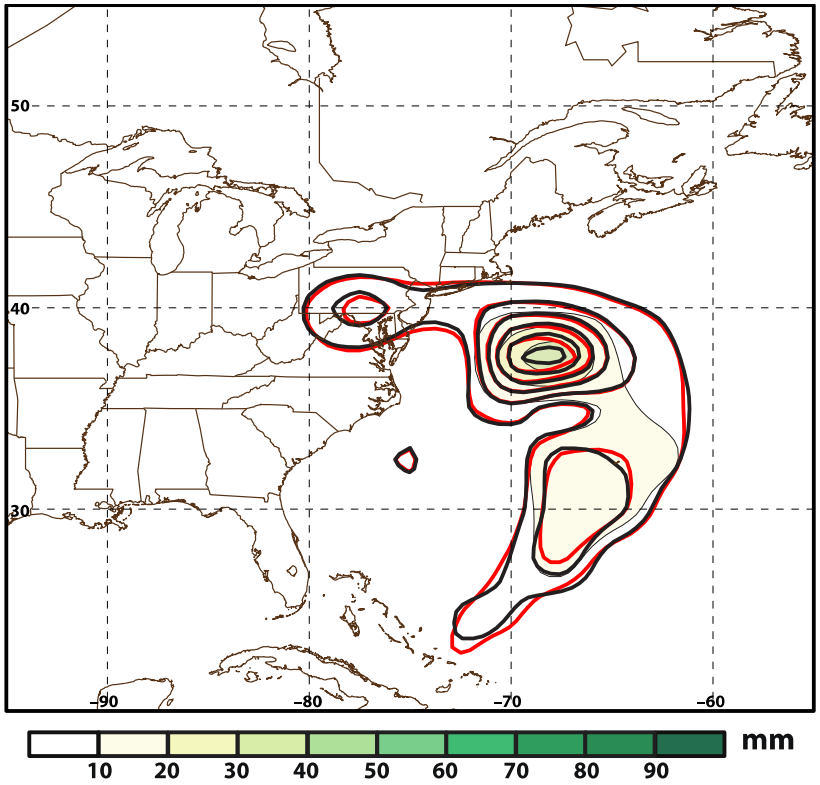
Ens. Mean — Analysis

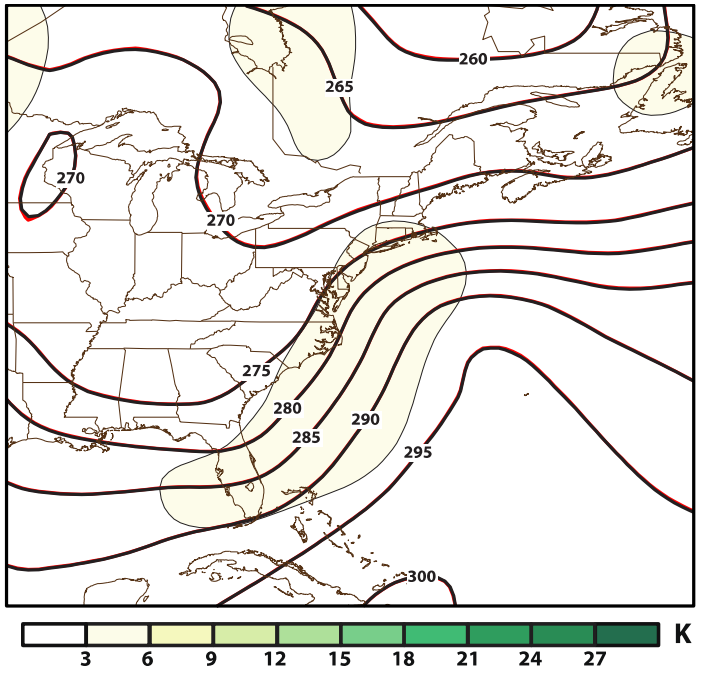
GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

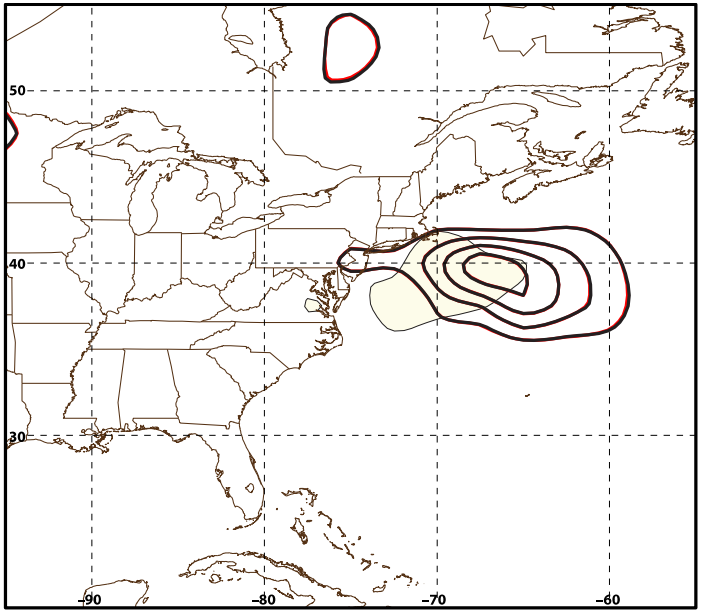
00-h Forecast

6-h Accumulated Precipitation; Every 10 mm





925 hPa Pot. Temp; Every 5 K



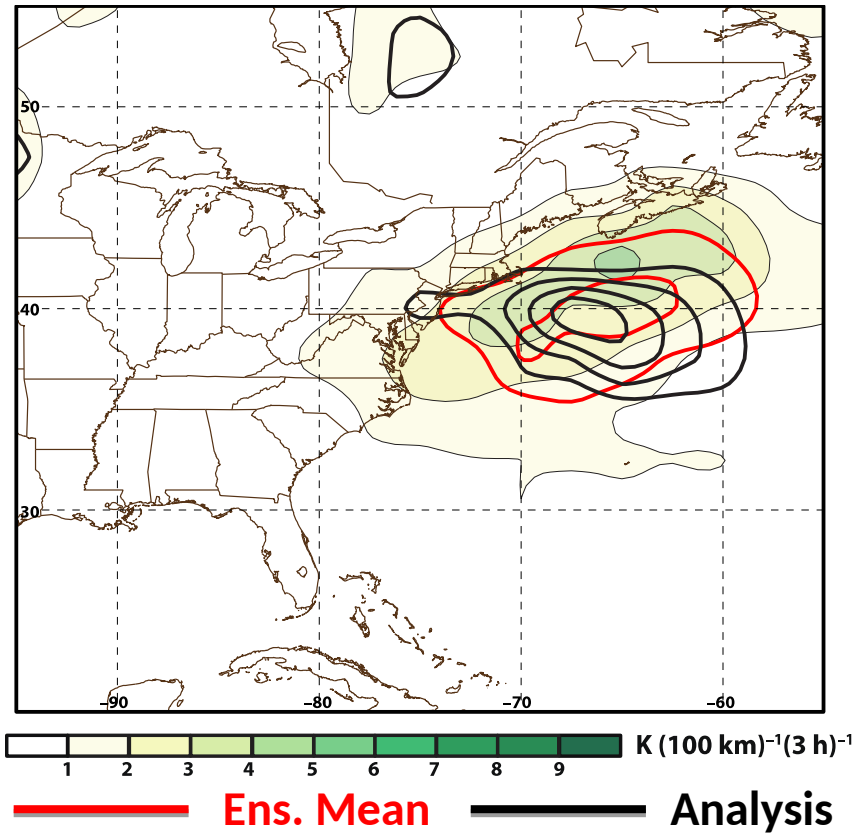
925 hPa Fronto-genesis; Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$

Ens. Mean — Analysis

GEFS Forecasts Verifying
1800 UTC 23 Jan 2016

120-h Forecast

925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



$$F_{2D} = \frac{|\nabla\theta|}{2}[E\cos(2\beta) - D]$$

E = *Total Deformation*

D = *Divergence*

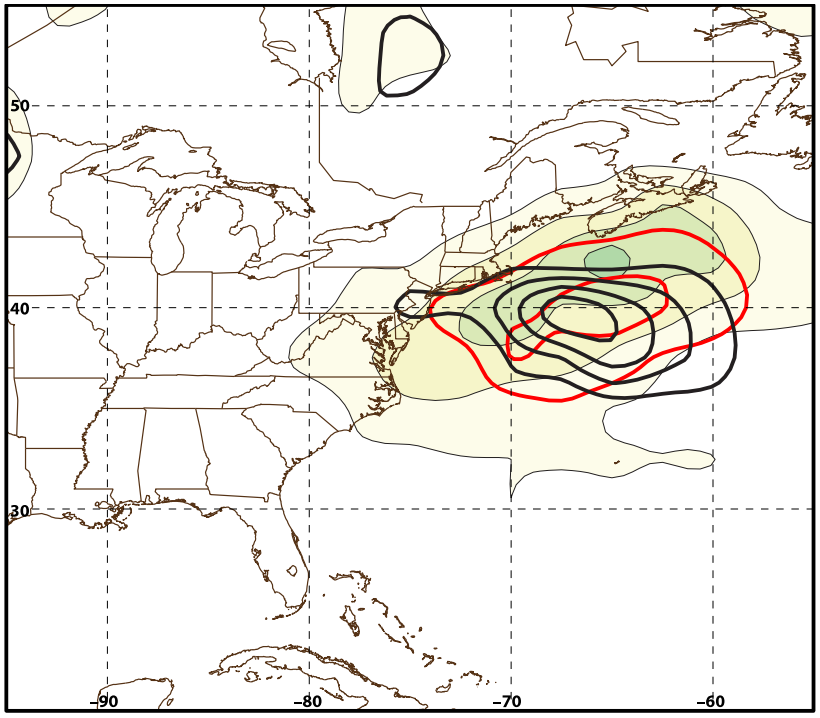
β = *Angle Betw. Isentropes and Axis of Dilatation*

GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

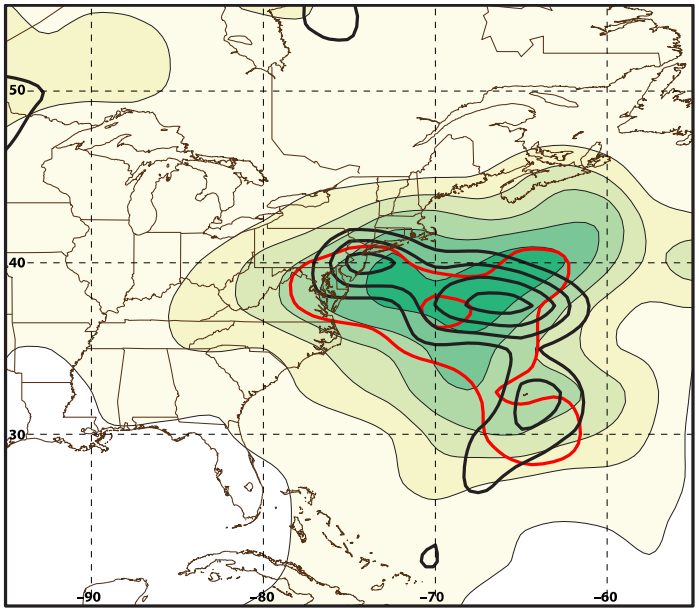
120-h Forecast

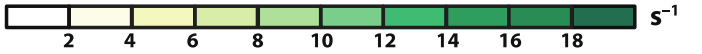
925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



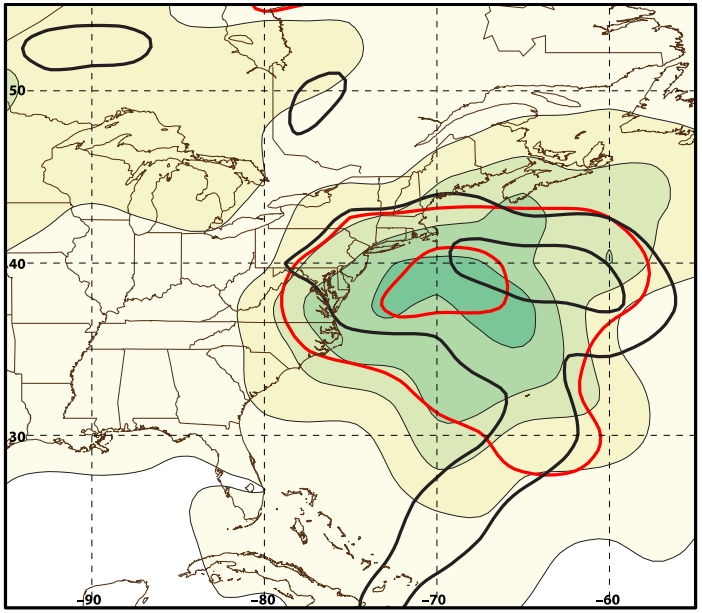
Ens. Mean Analysis

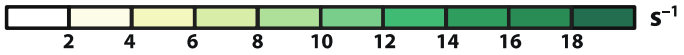
925 hPa Convergence;
Every
2x10^{-5} s^{-1}





925 hPa Deformation;
Every
2x10^{-5} s^{-1}

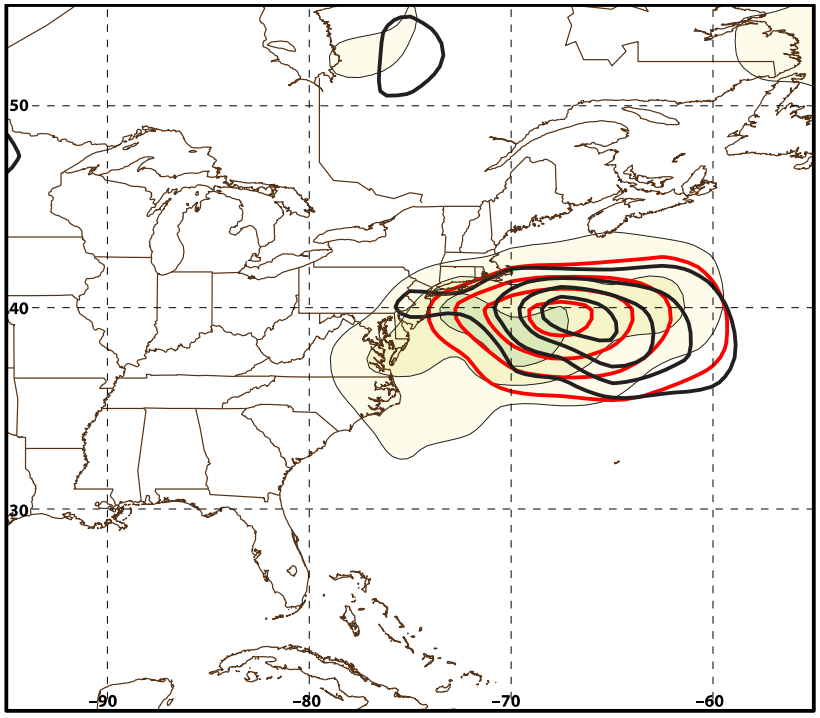




GEFS Forecasts Verifying
1800 UTC 23 Jan 2016

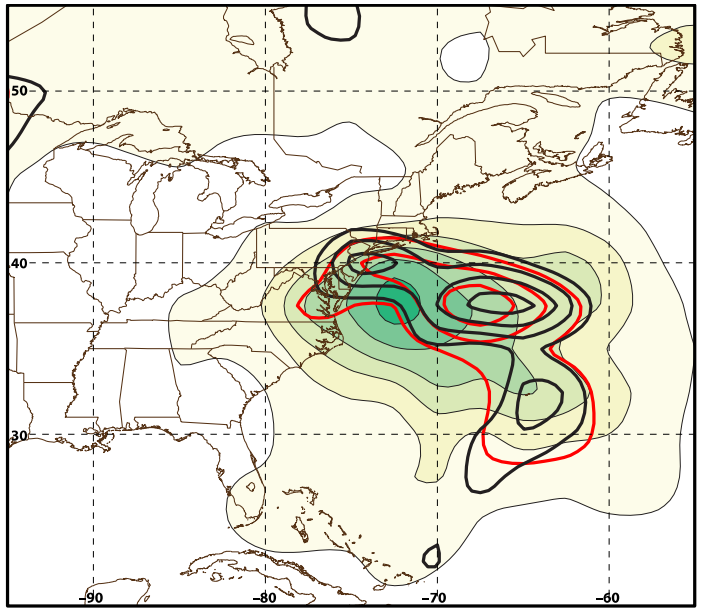
96-h Forecast

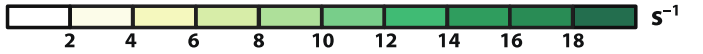
925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



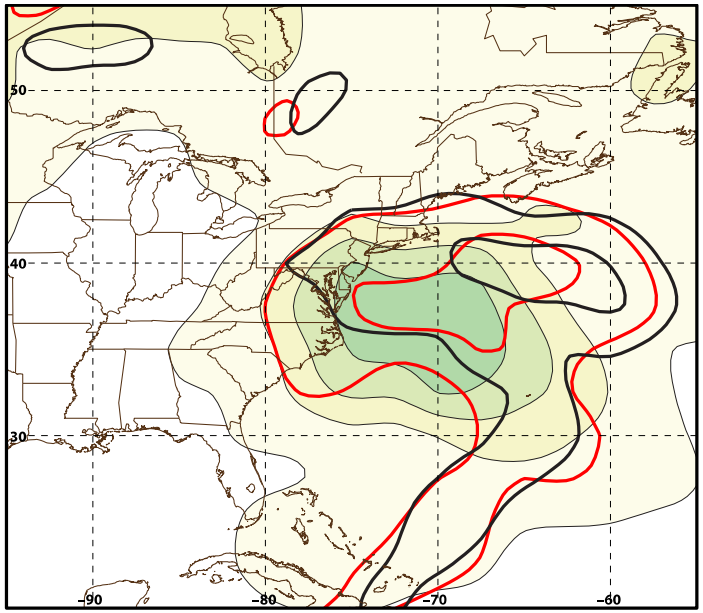
Ens. Mean Analysis

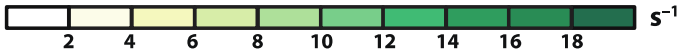
925 hPa Convergence;
Every
2x10^{-5} s^{-1}





925 hPa Deformation;
Every
2x10^{-5} s^{-1}



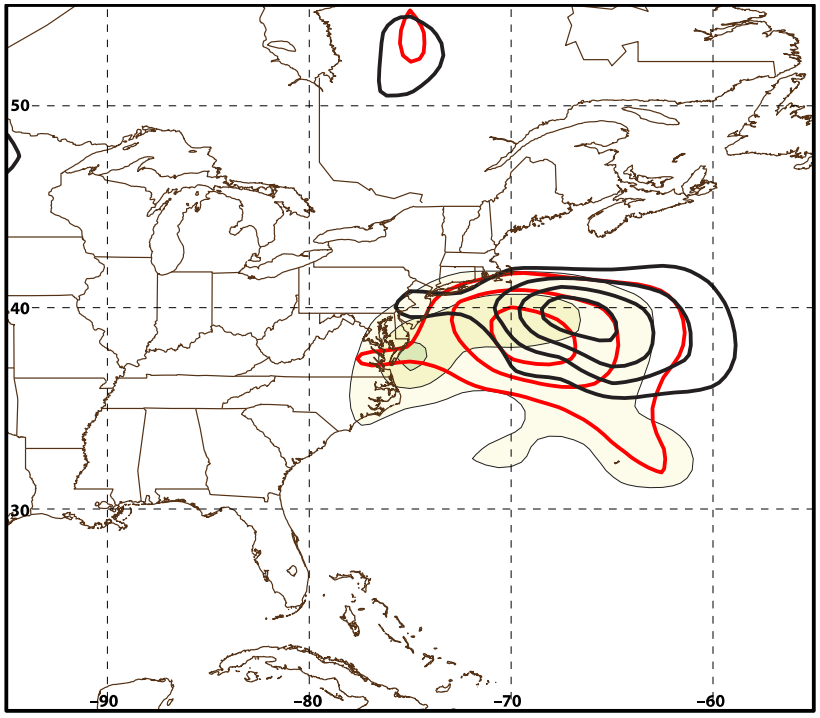


GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

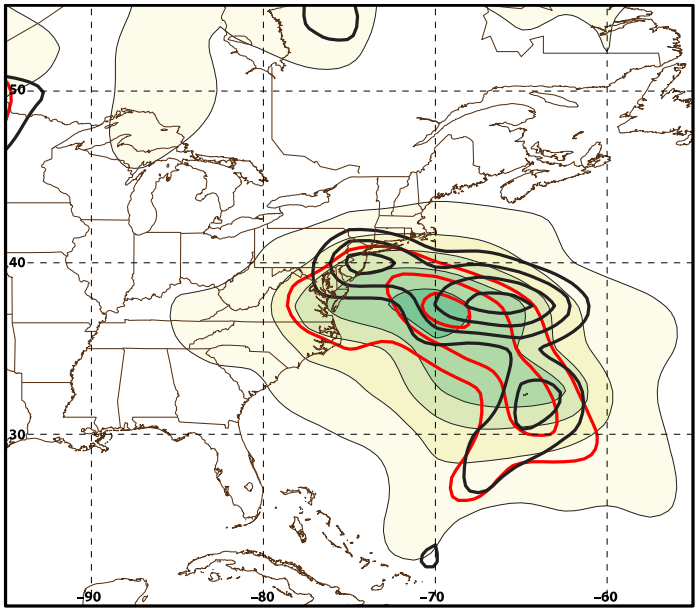
72-h Forecast

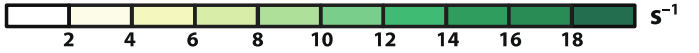
925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



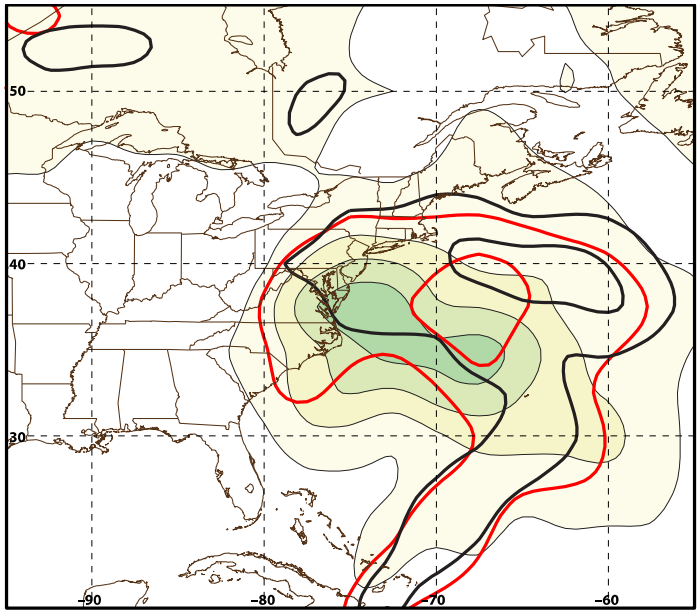
Ens. Mean Analysis

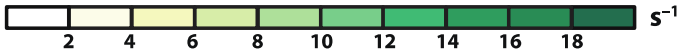
925 hPa Convergence;
Every
2x10^{-5} s^{-1}





925 hPa Deformation;
Every
2x10^{-5} s^{-1}

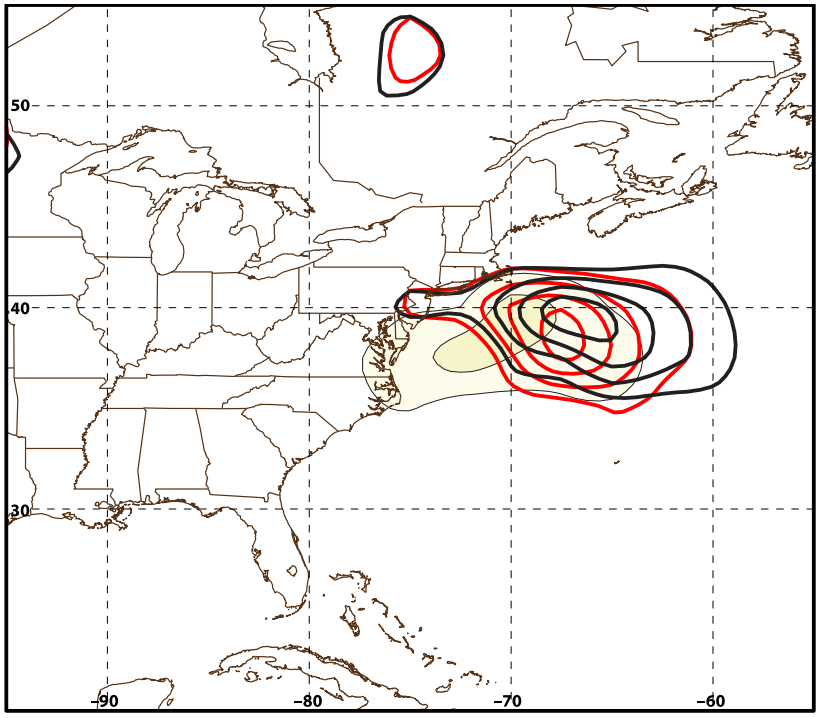




GEFS Forecasts Verifying
1800 UTC 23 Jan 2016

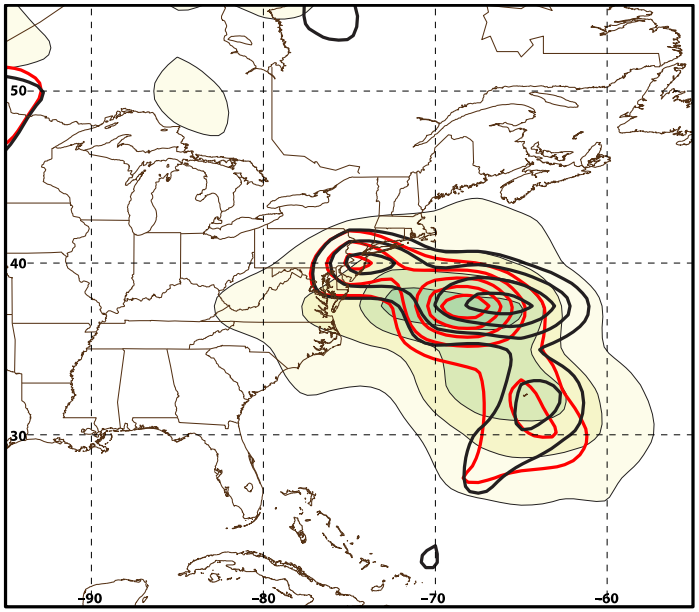
48-h Forecast

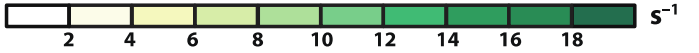
925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



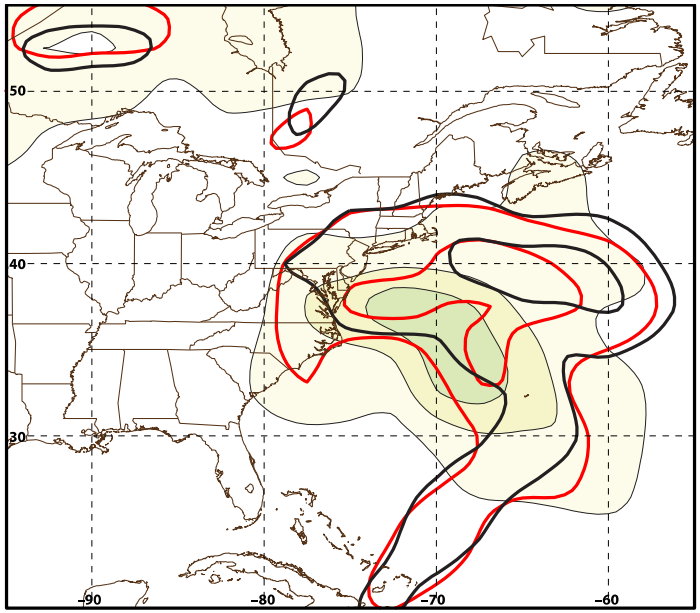
Ens. Mean Analysis

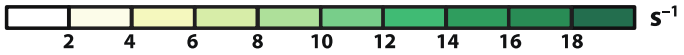
925 hPa Convergence;
Every
2x10^{-5} s^{-1}





925 hPa Deformation;
Every
2x10^{-5} s^{-1}



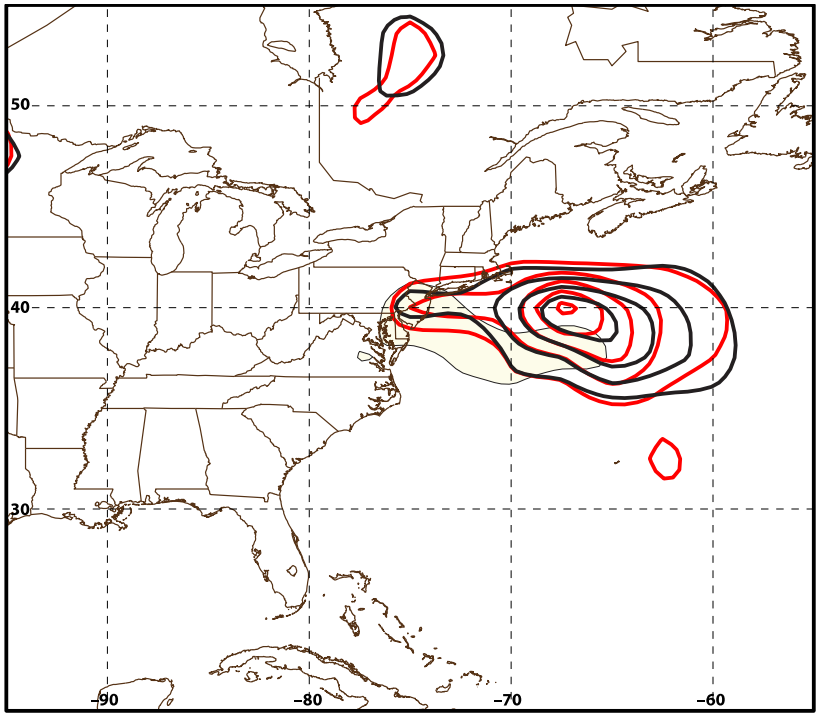


GEFS Forecasts Verifying

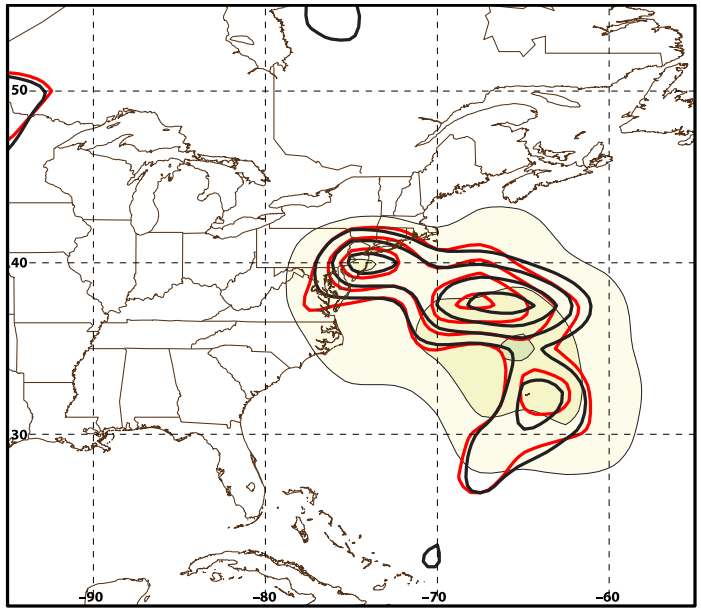
1800 UTC 23 Jan 2016

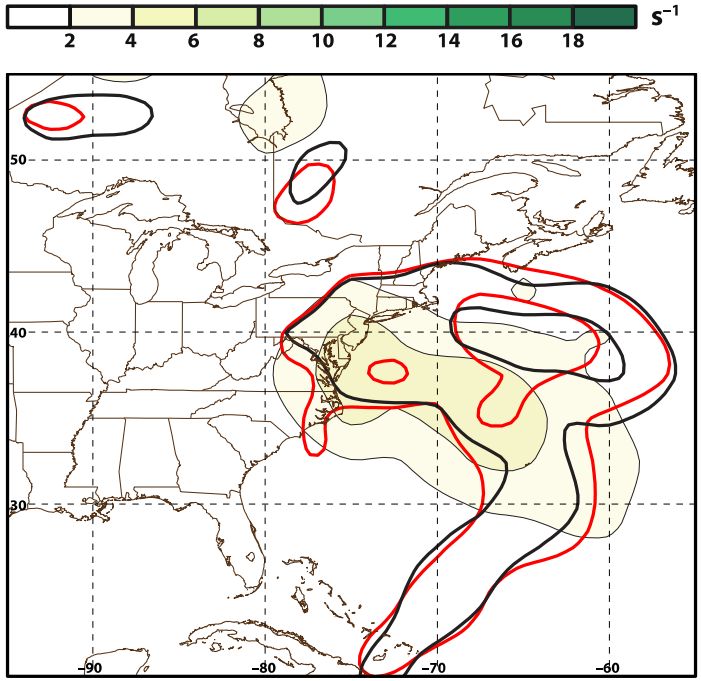
24-h Forecast

925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



Ens. Mean Analysis





925 hPa Convergence;
Every
2x10^{-5} s^{-1}

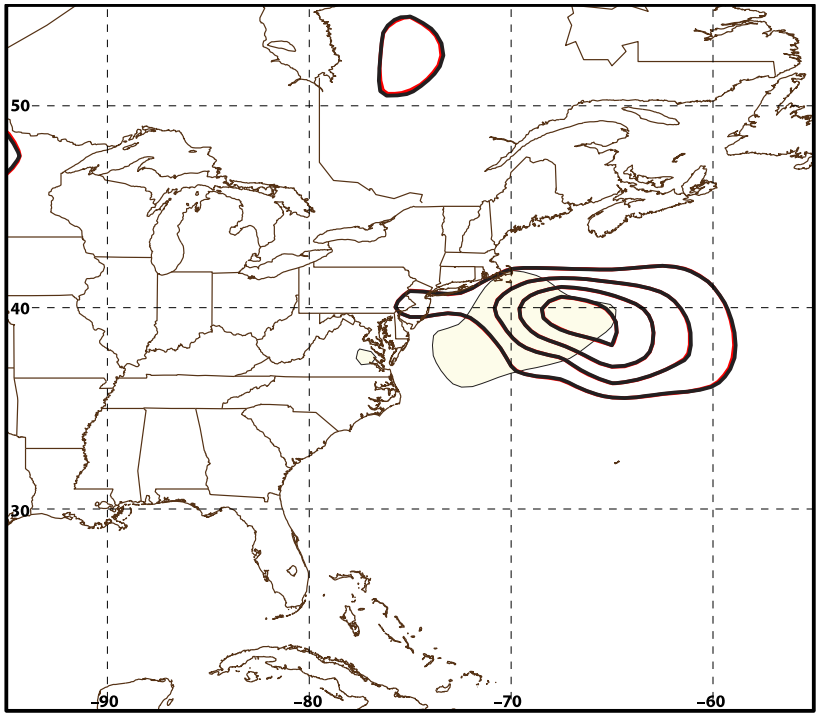
925 hPa Deformation;
Every
2x10^{-5} s^{-1}

GEFS Forecasts Verifying

1800 UTC 23 Jan 2016

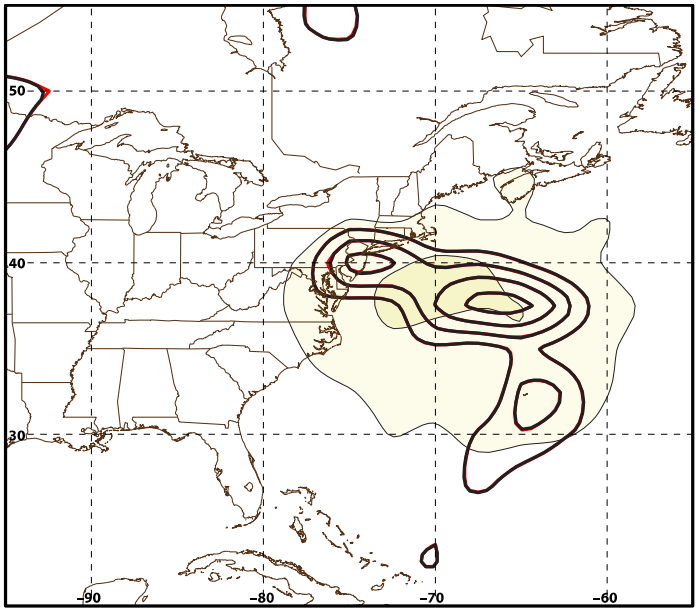
00-h Forecast

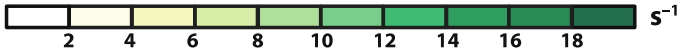
925 hPa Frontogenesis;
Every 0.5 K (100 km)$^{-1}$ (3 h)$^{-1}$



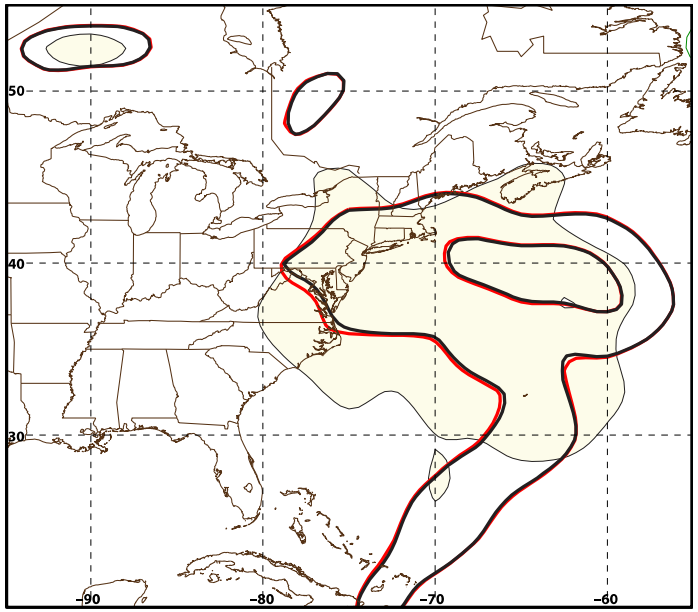
Ens. Mean Analysis

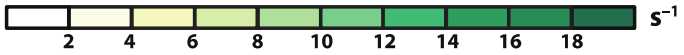
925 hPa Convergence;
Every
2x10^{-5} s^{-1}





925 hPa Deformation;
Every
2x10^{-5} s^{-1}

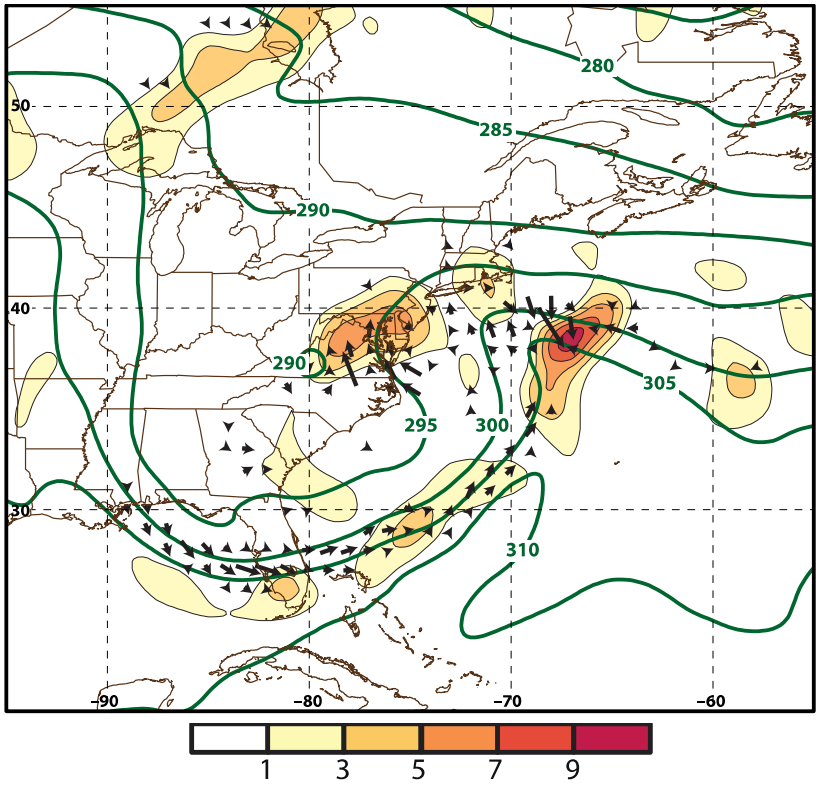




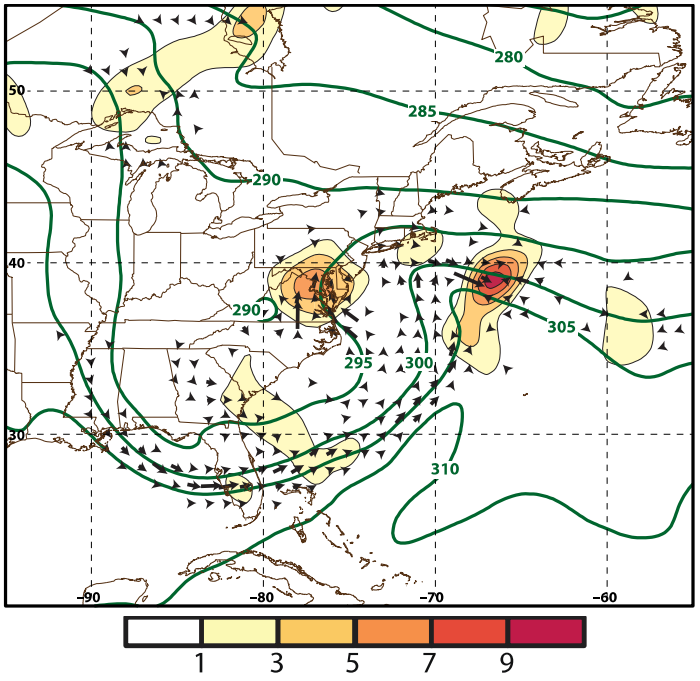
GFS Analysis

1800 UTC 23 Jan 2016

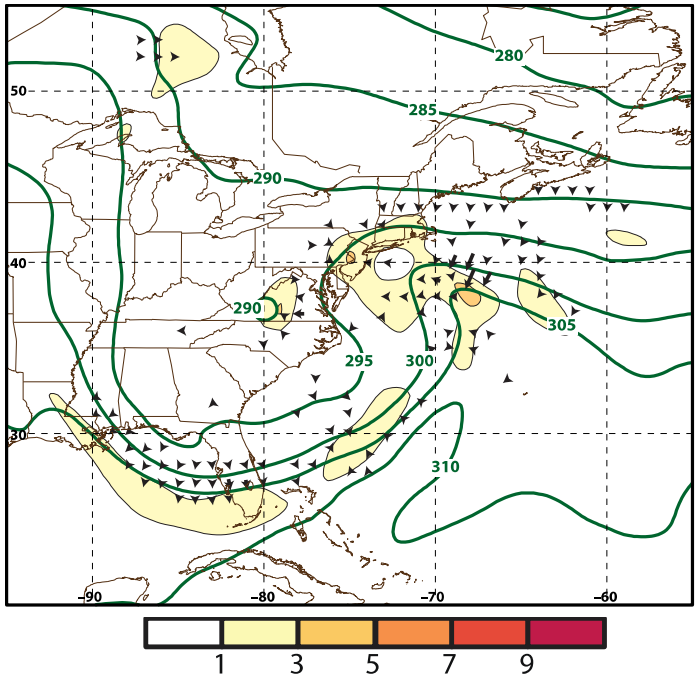
700 hPa Q-vector Convergence, Q-vectors, and Pot. Temp.



700 hPa Q_s Convergence, Q_s vectors, and Pot. Temp.



700 hPa Q_n Convergence, Q_n vectors, and Pot. Temp.



Case Summary

- The event was well-forecasted by the operational GFS as many as **9 days** prior to the event.

- Considerable uncertainty with respect to the **amount and location of precipitation** along the bent-back warm front lingered prior to the event.

- The **spread in several diagnostics for vertical motion** reflected the uncertainty in accurately forecasting total snow accumulations.

22–23 December 2013 Ice Storm

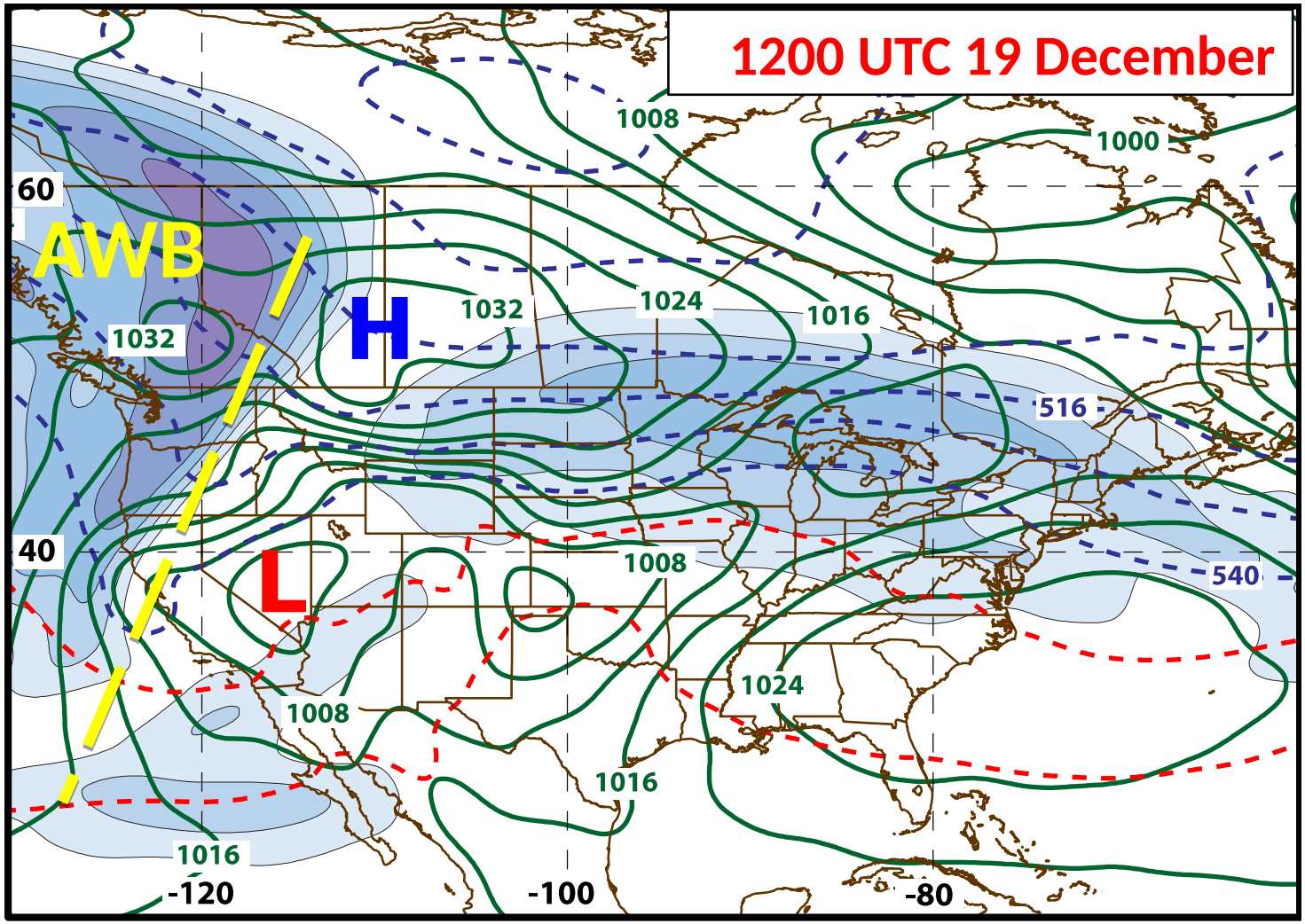
> 30 mm of ice in some locations.

> 400,000 lost power in Ontario, Quebec, and in the Canadian Maritimes.

Gusty winds in excess of **15 m s^{-1}**.

The Canadian Press

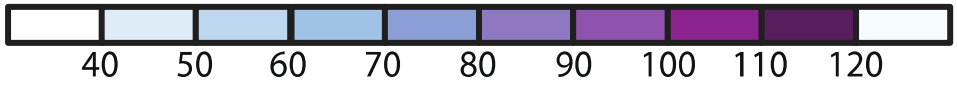
22–23 December 2013 Ice Storm



250 hPa Wind Speed ($m\ s^{-1}$; fill)

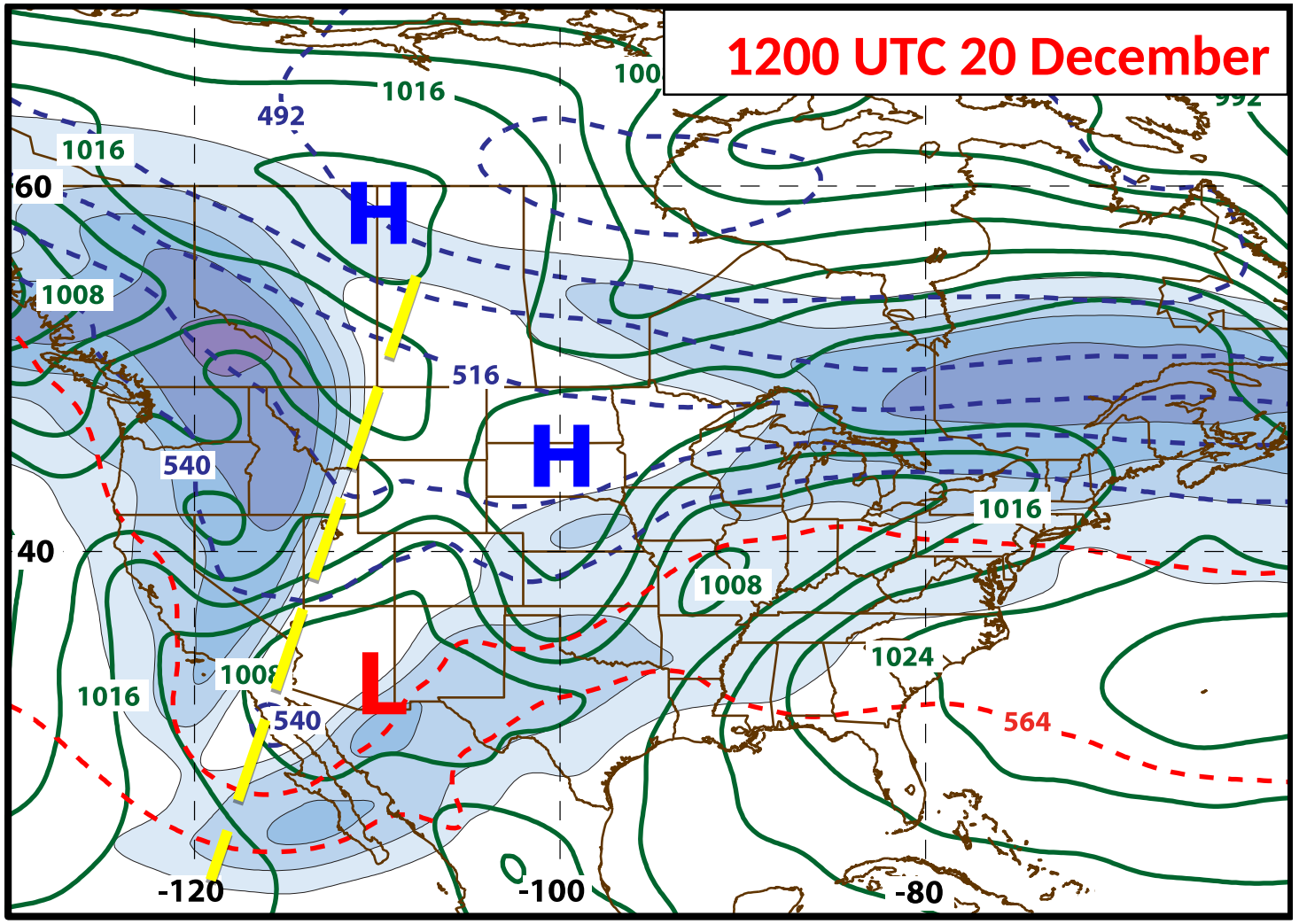
1000–500 hPa Thickness (dam; dashed)

Mean SLP (hPa; green)



Trough Axis

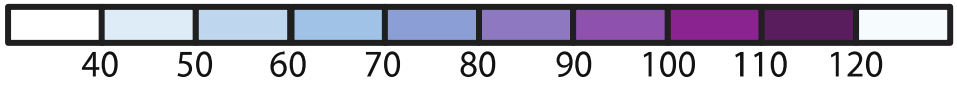
22–23 December 2013 Ice Storm



250 hPa Wind Speed ($m\ s^{-1}$; fill)

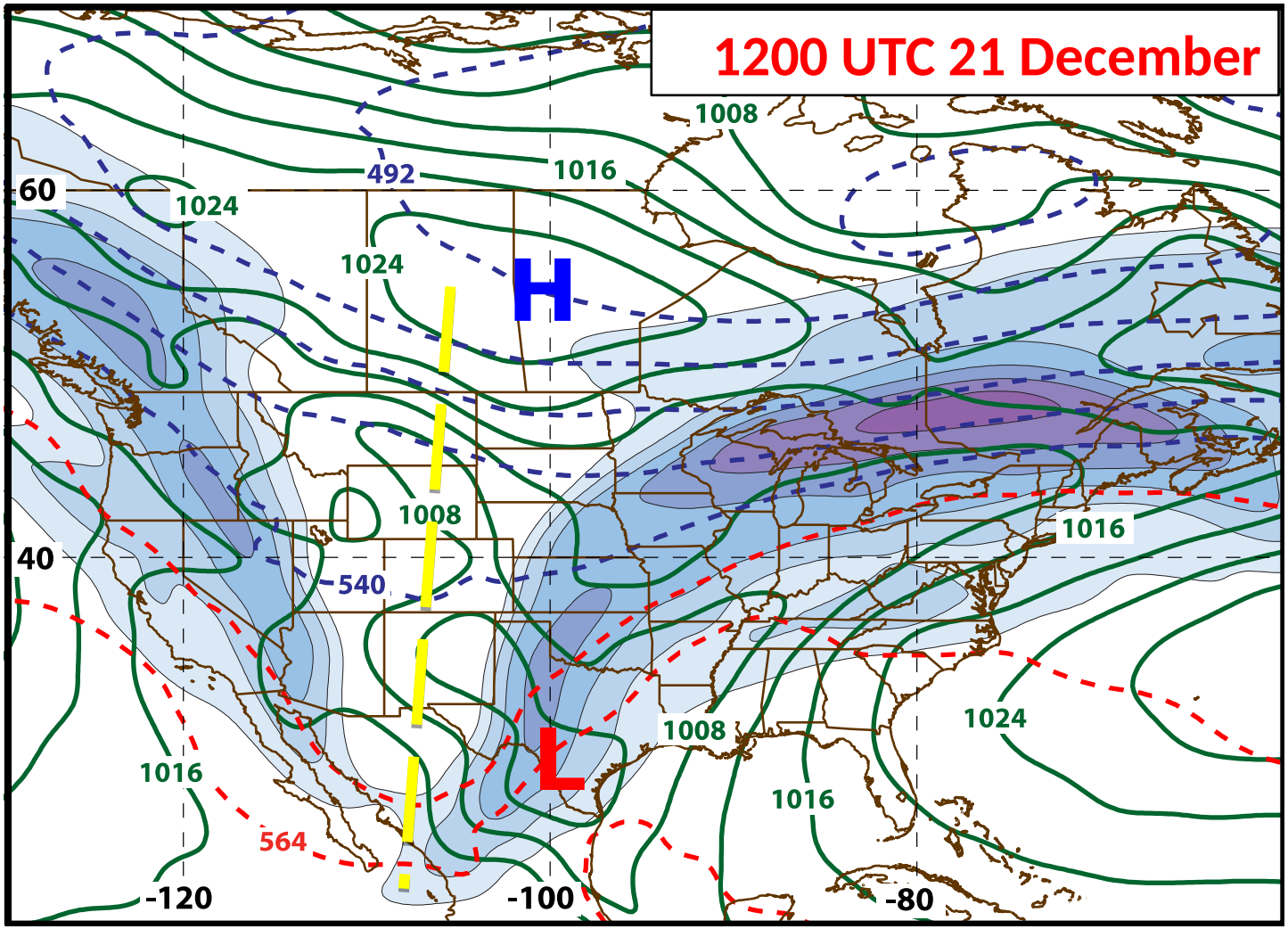
1000–500 hPa Thickness (dam; dashed)

Mean SLP (hPa; green)



Trough Axis

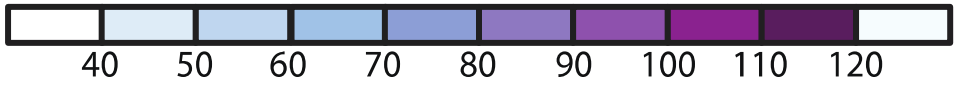
22–23 December 2013 Ice Storm



250 hPa Wind Speed ($m\ s^{-1}$; fill)

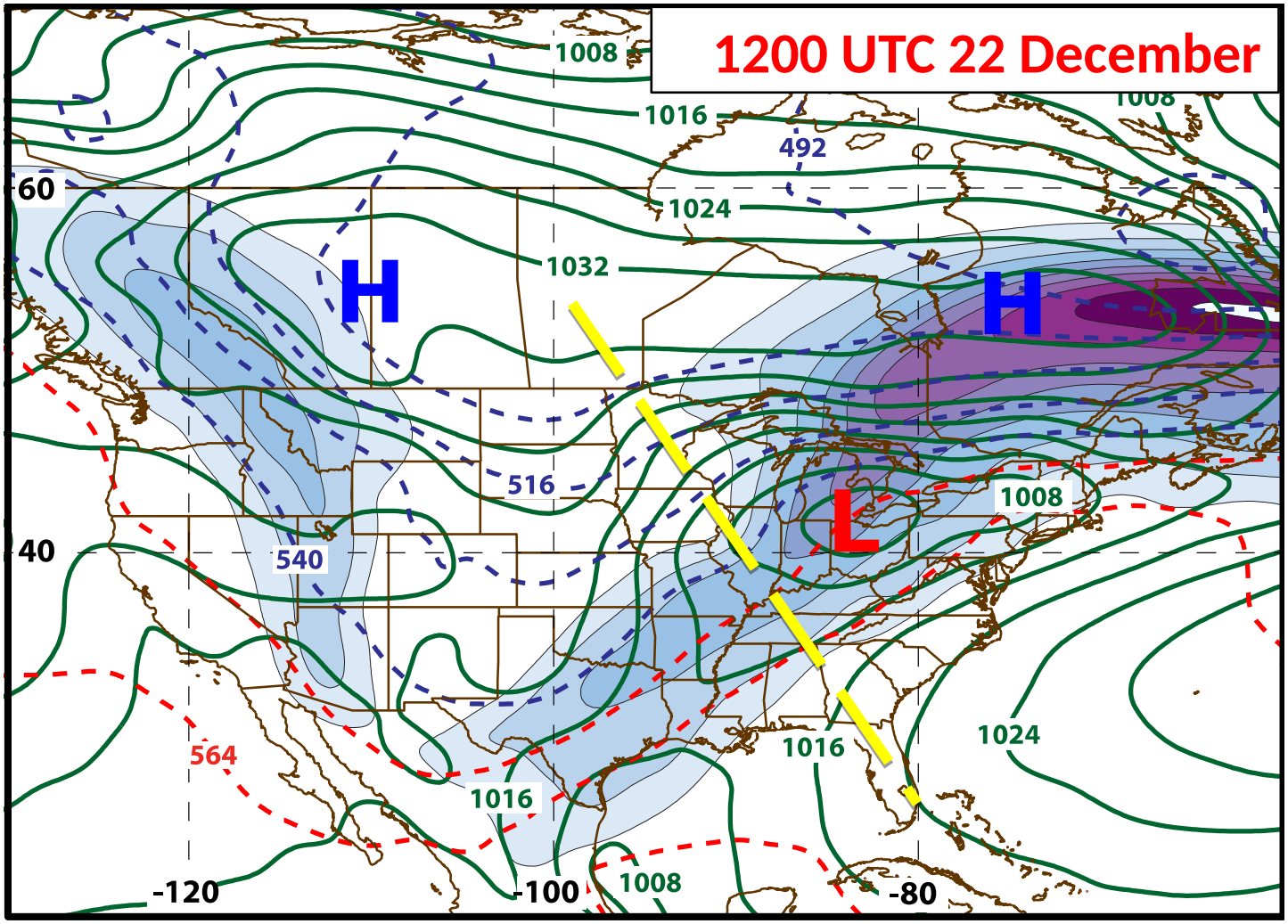
1000–500 hPa Thickness (dam; dashed)

Mean SLP (hPa; green)



Trough Axis

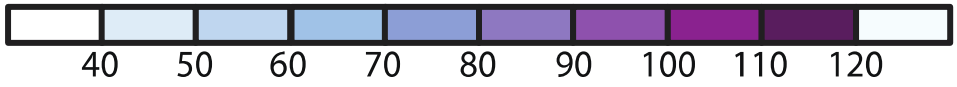
22–23 December 2013 Ice Storm



250 hPa Wind Speed ($m\ s^{-1}$; fill)

1000–500 hPa Thickness (dam; dashed)

Mean SLP (hPa; green)

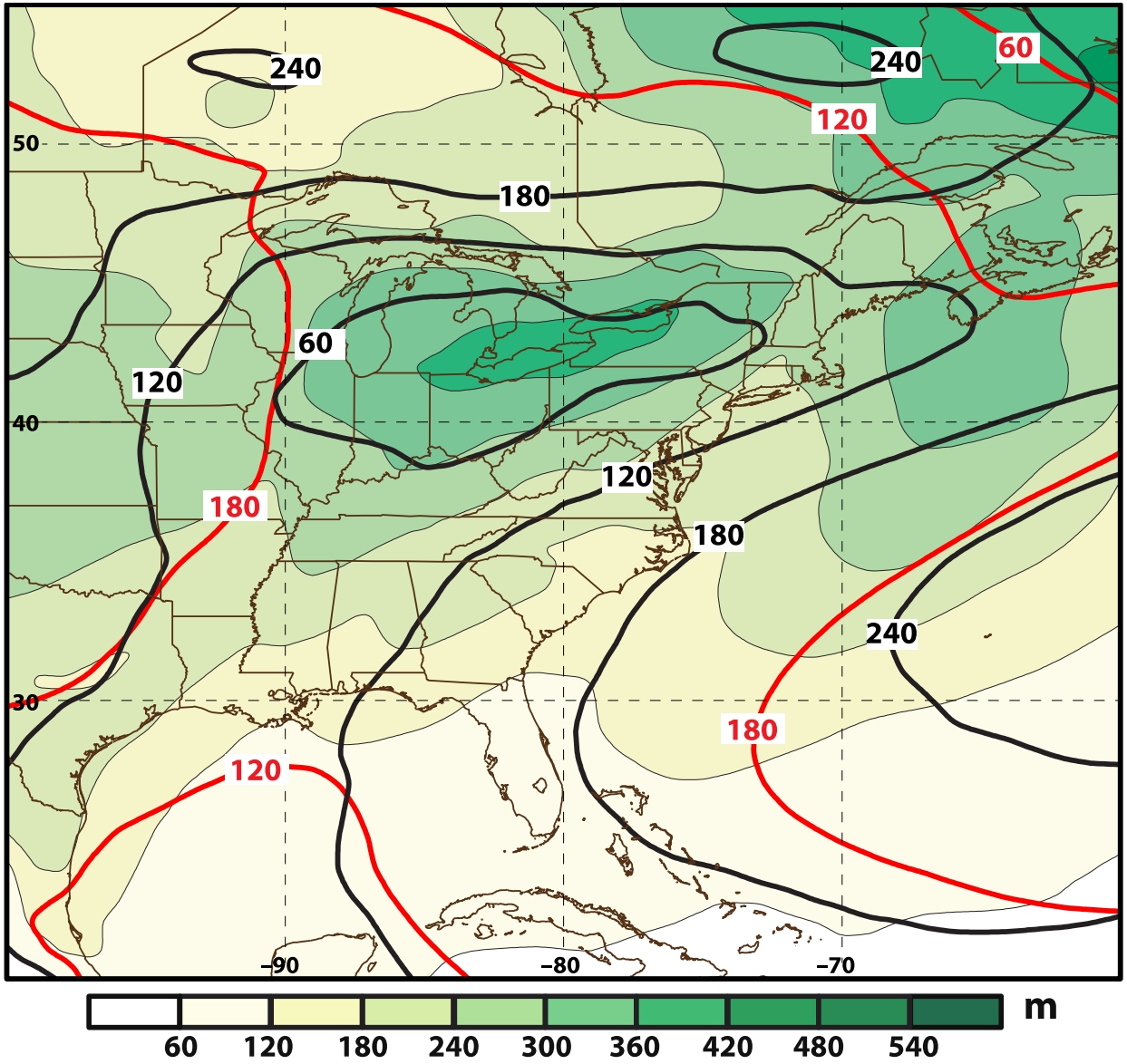


Trough Axis

22–23 December 2013 Ice Storm

240-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



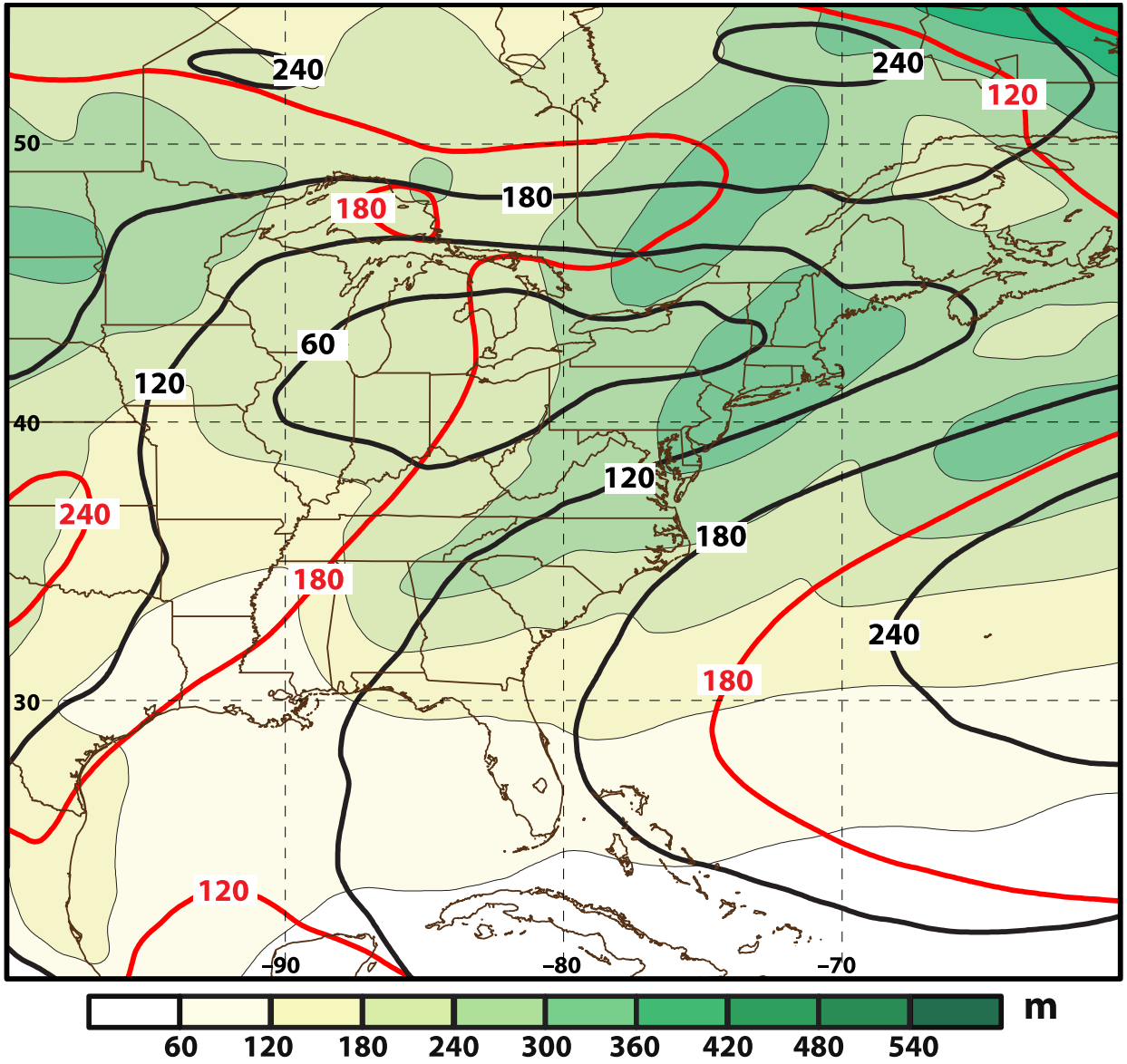
GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm

216-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



GEFS Ens. Mean

Analysis

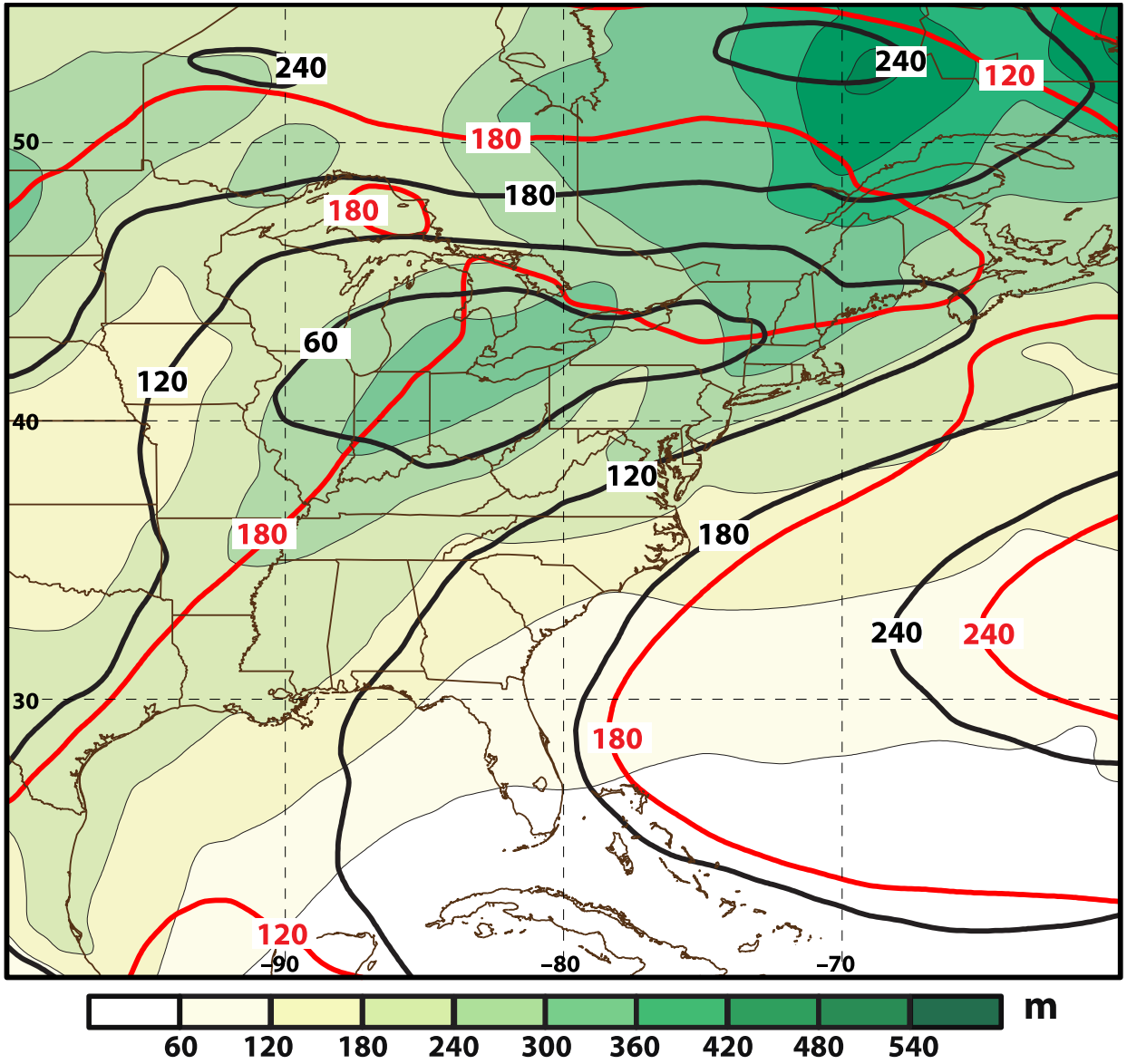
22–23 December 2013 Ice Storm

192-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December

GEFS Ens. Mean

Analysis



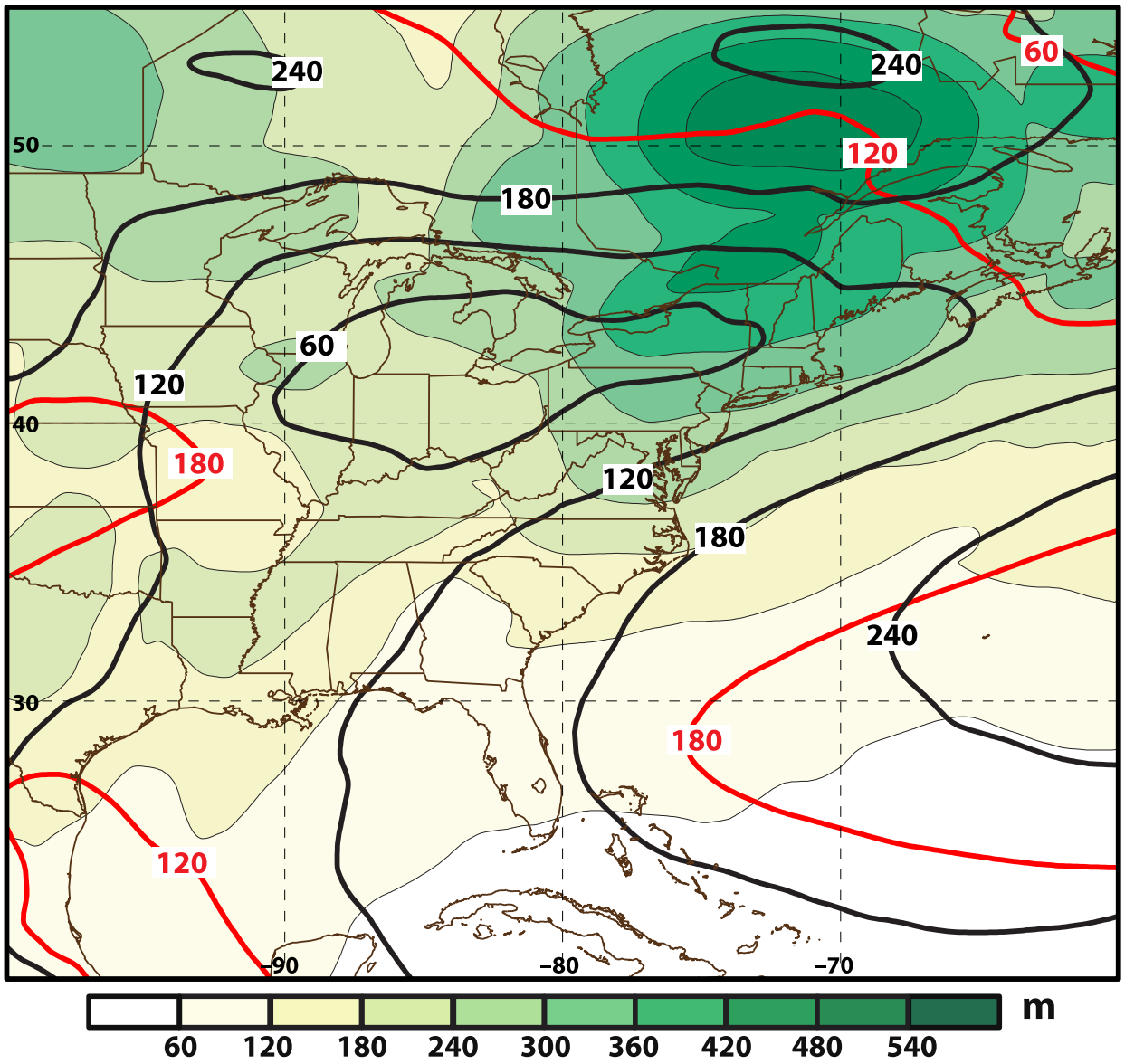
22–23 December 2013 Ice Storm

168-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December

GEFS Ens. Mean

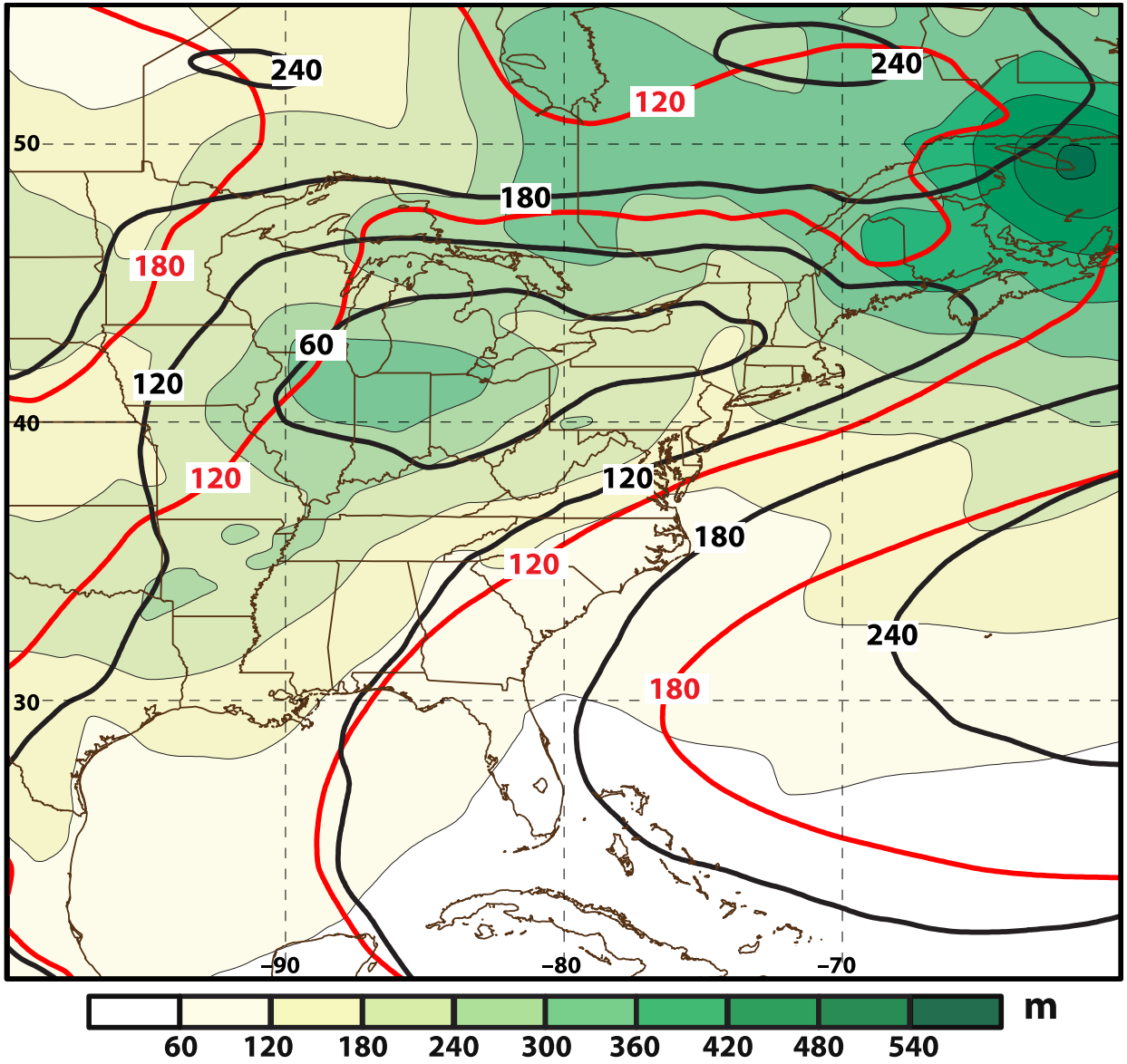
Analysis



22–23 December 2013 Ice Storm

144-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



GEFS Ens. Mean

Analysis

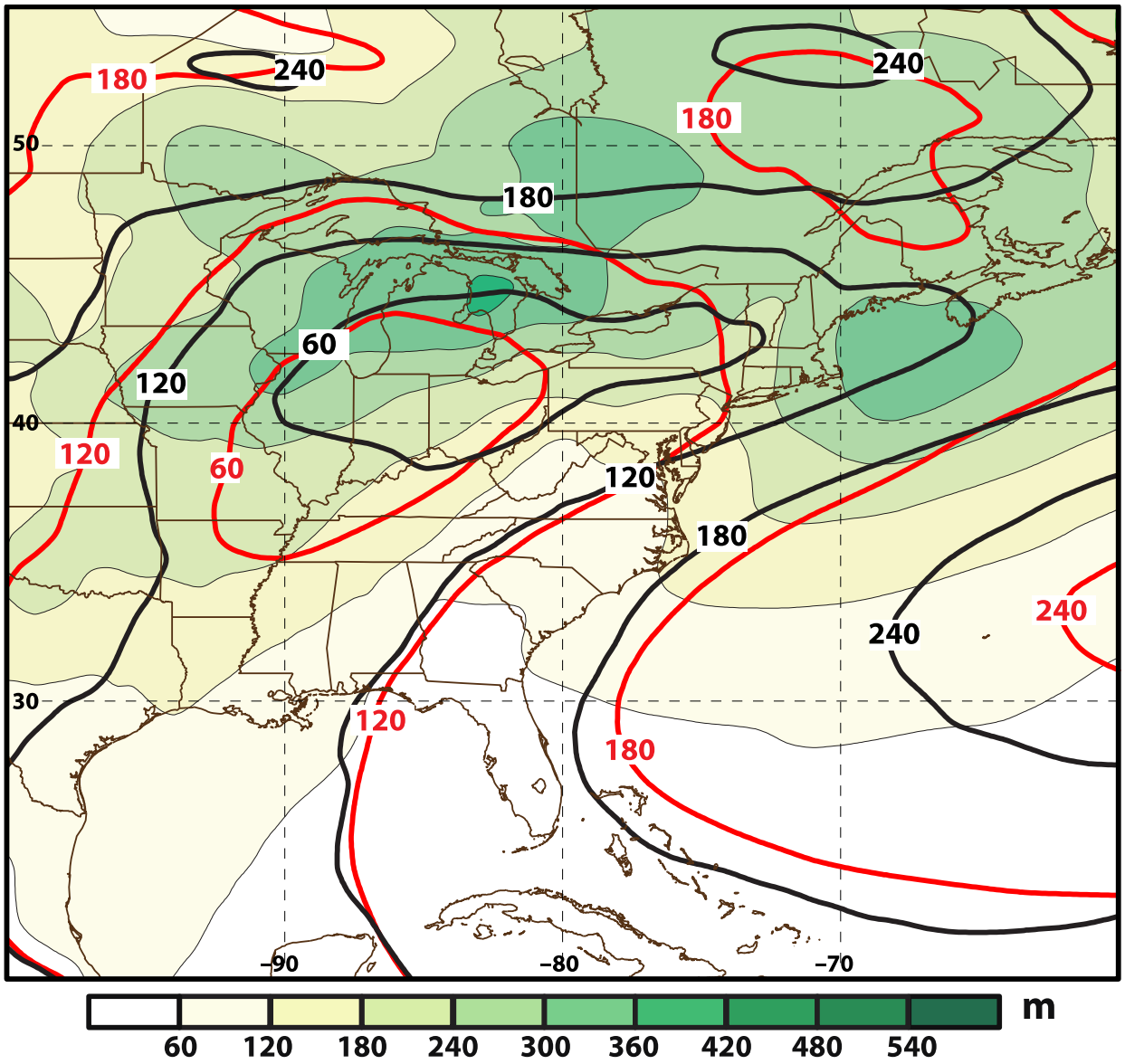
22–23 December 2013 Ice Storm

120-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December

GEFS Ens. Mean

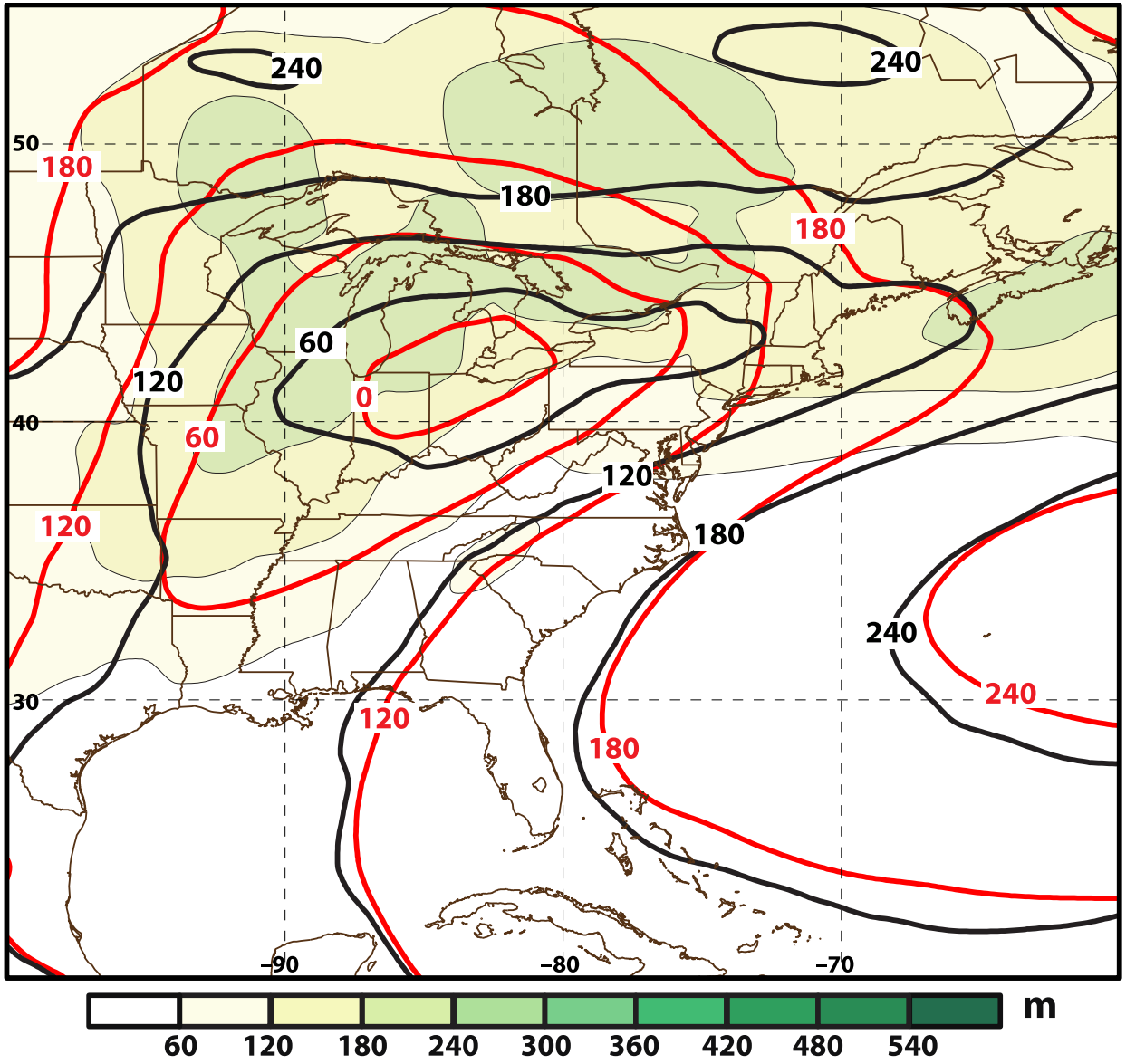
Analysis



22–23 December 2013 Ice Storm

96-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



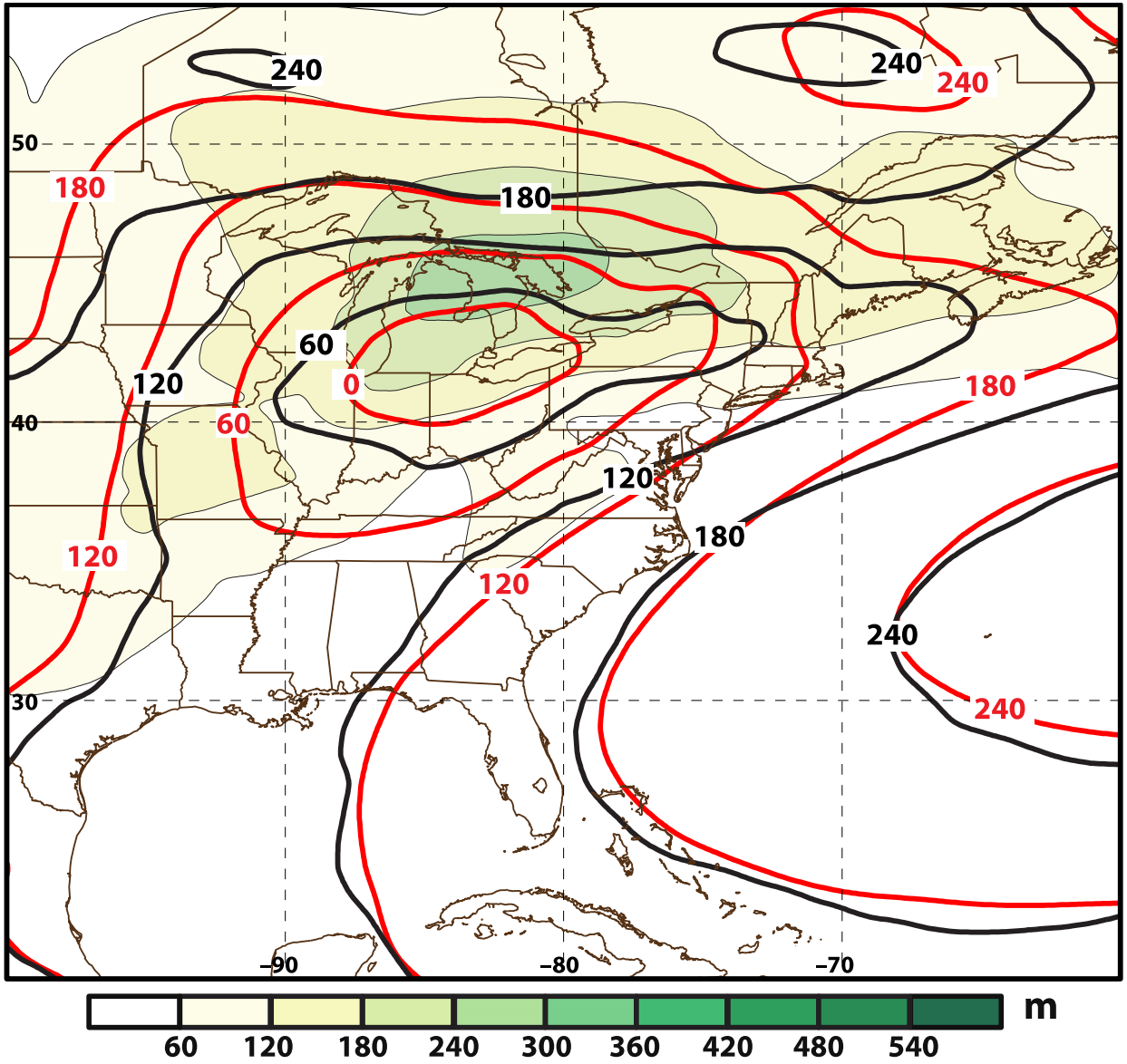
GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm

72-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



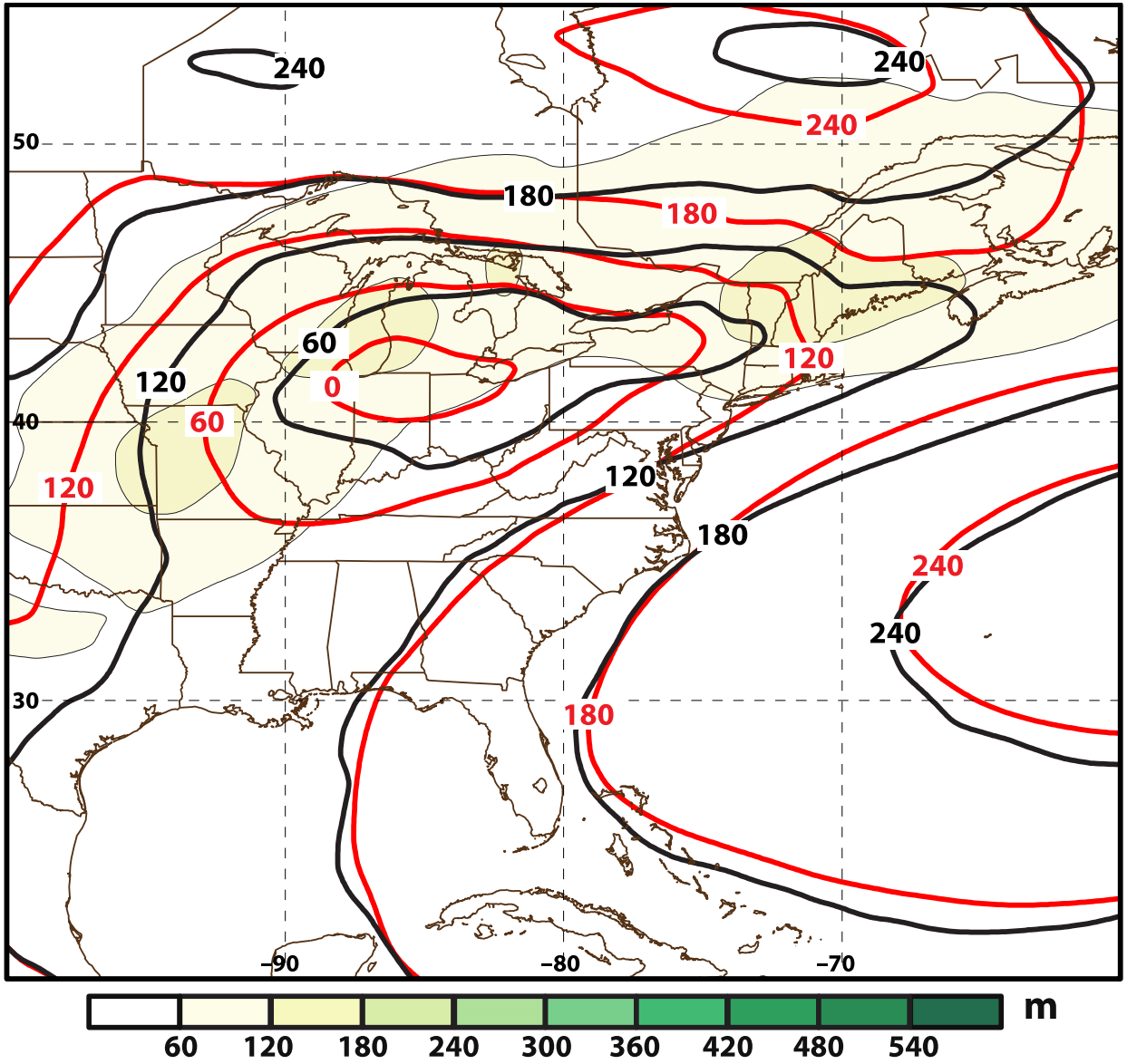
GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm

48-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



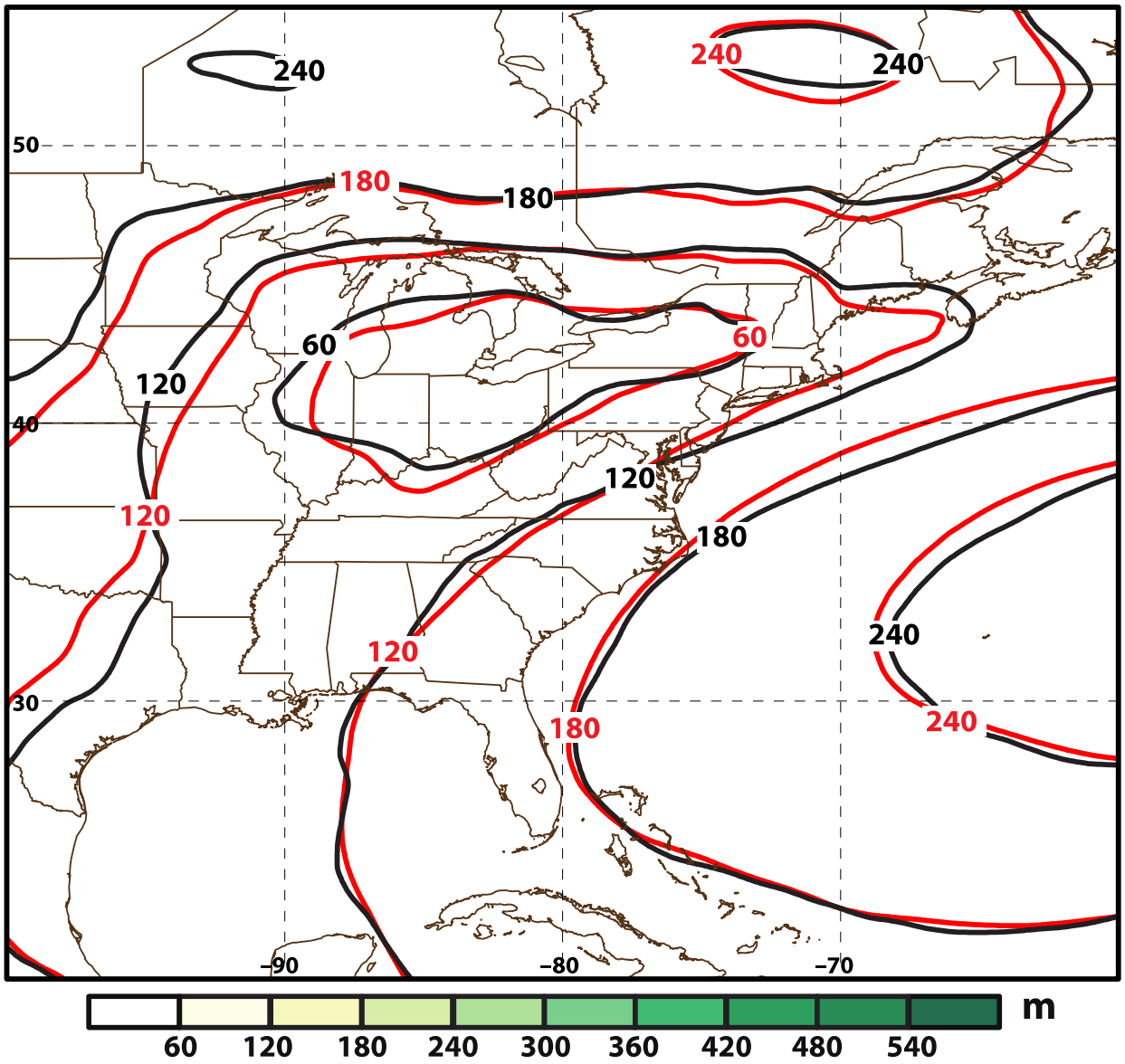
GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm

24-h Forecast

1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December



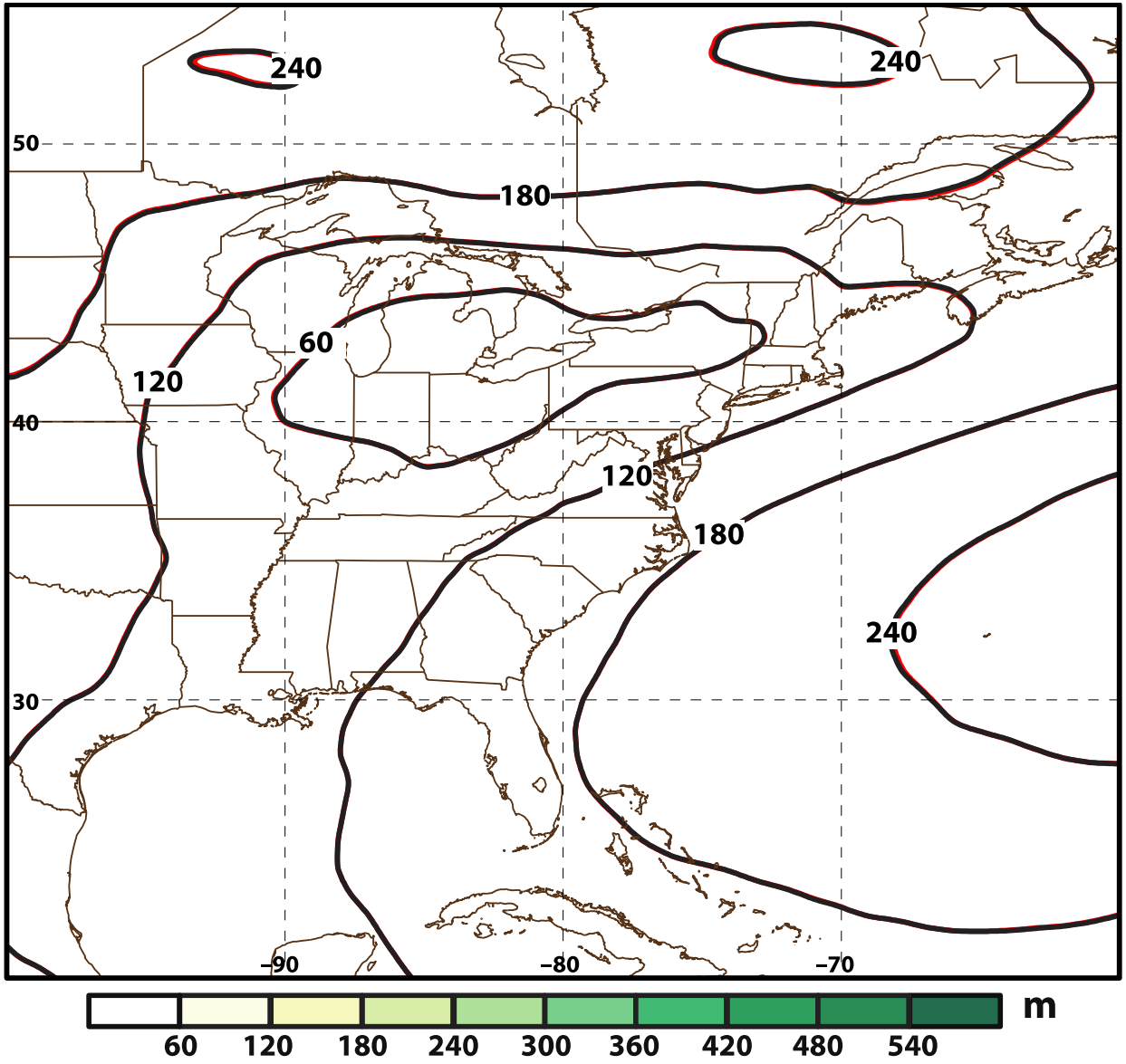
GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm

00-h Forecast

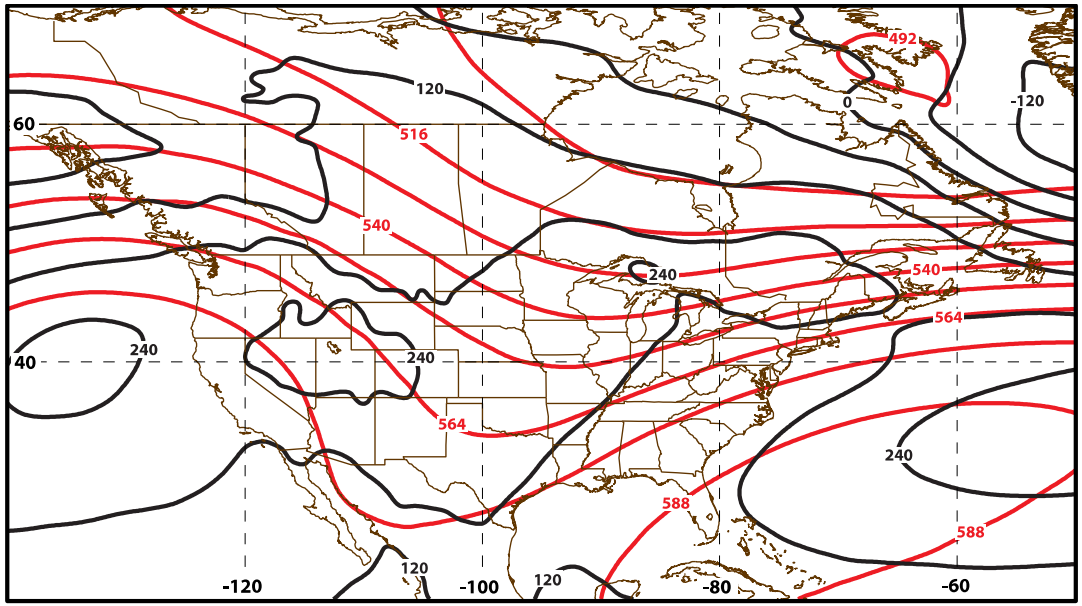
1000 hPa Geo. Height (m)
Verifying
1200 UTC
22 December

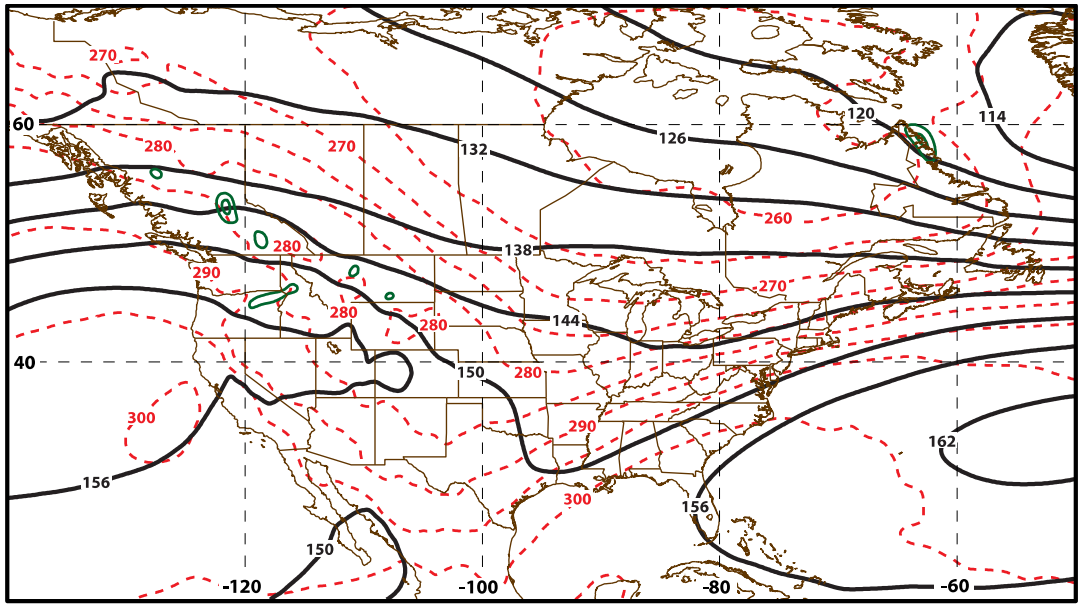


GEFS Ens. Mean

Analysis

22–23 December 2013 Ice Storm





14 December – 192 h

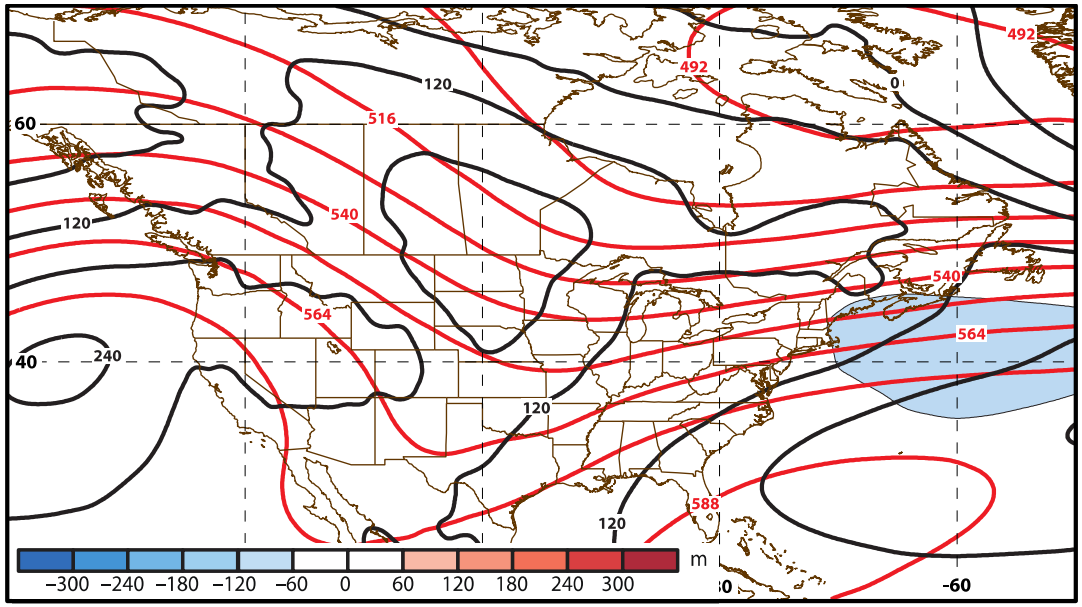
1000 hPa Geo. Height (m; black)

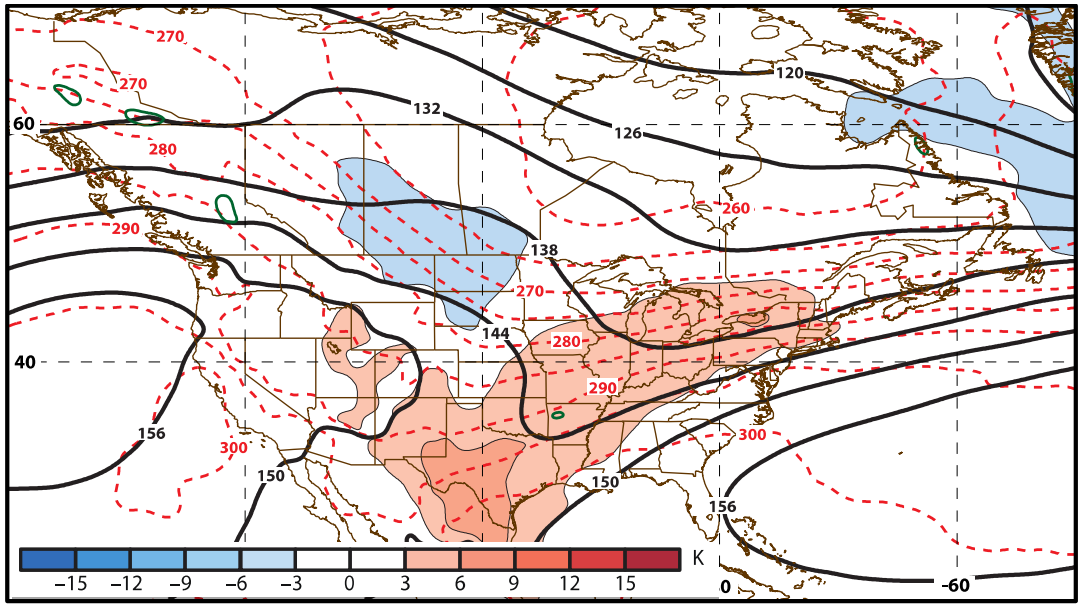
500 hPa Geo. Height (dam; red)

850 hPa Geo. Height (m; black)

850 hPa Pot. Temp. (K; red)

22–23 December 2013 Ice Storm





16 December – 144 h

1000 hPa Geo. Height (m; black)

500 hPa Geo. Height (dam; red)

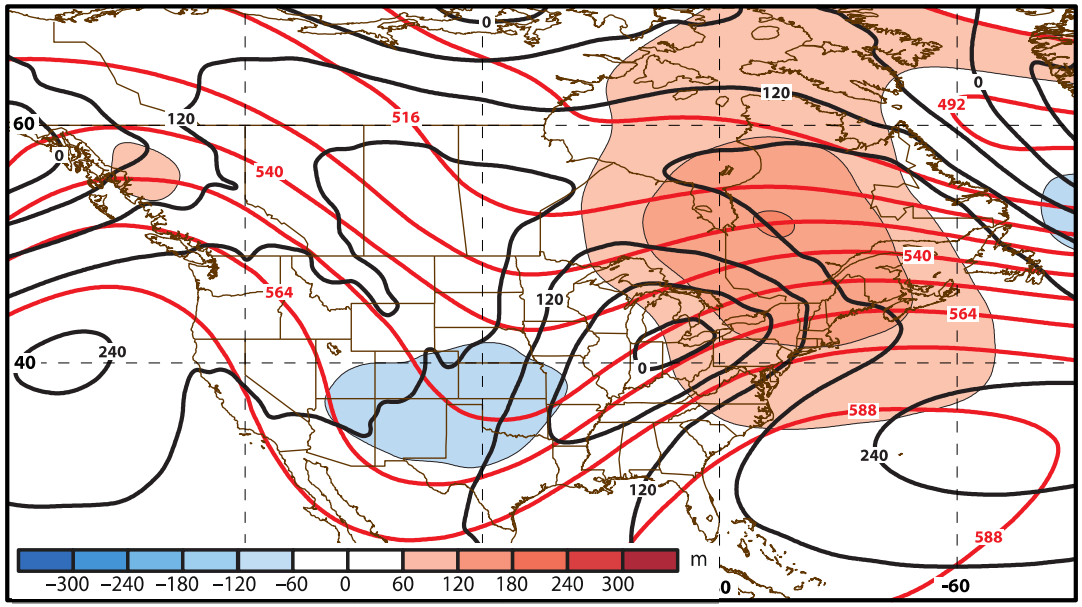
Difference in 500 hPa Geo. Height from forecast initialized 48-h earlier (m; shaded)

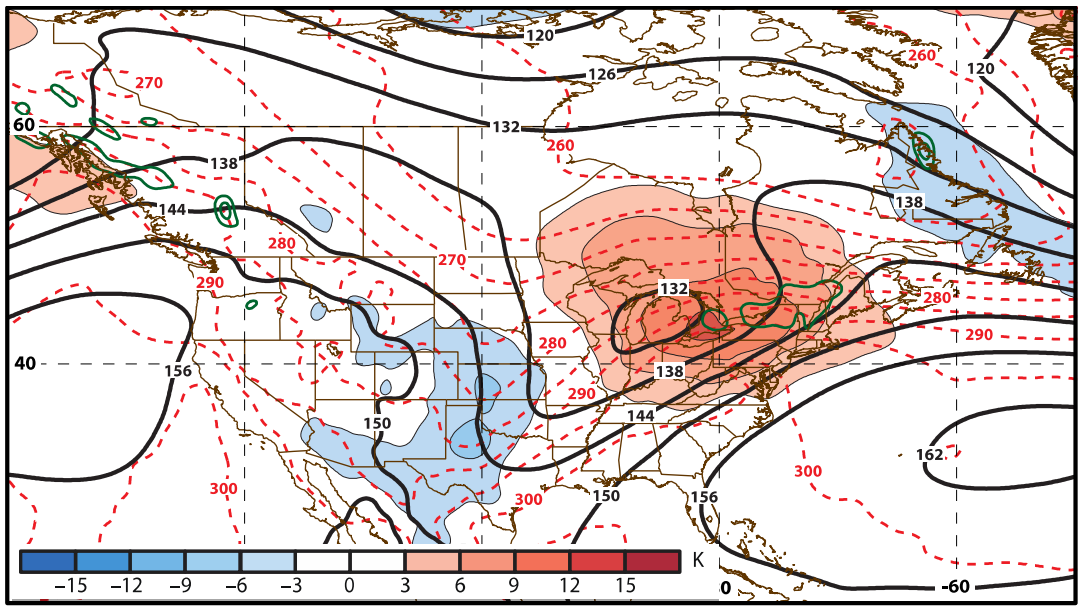
850 hPa Geo. Height (m; black)

850 hPa Pot. Temp. (K; red)

Difference in 850 hPa Pot. Temp. from forecast initialized 48-h earlier (K; shaded)

22–23 December 2013 Ice Storm





18 December – 96 h

1000 hPa Geo. Height (m; black)

500 hPa Geo. Height (dam; red)

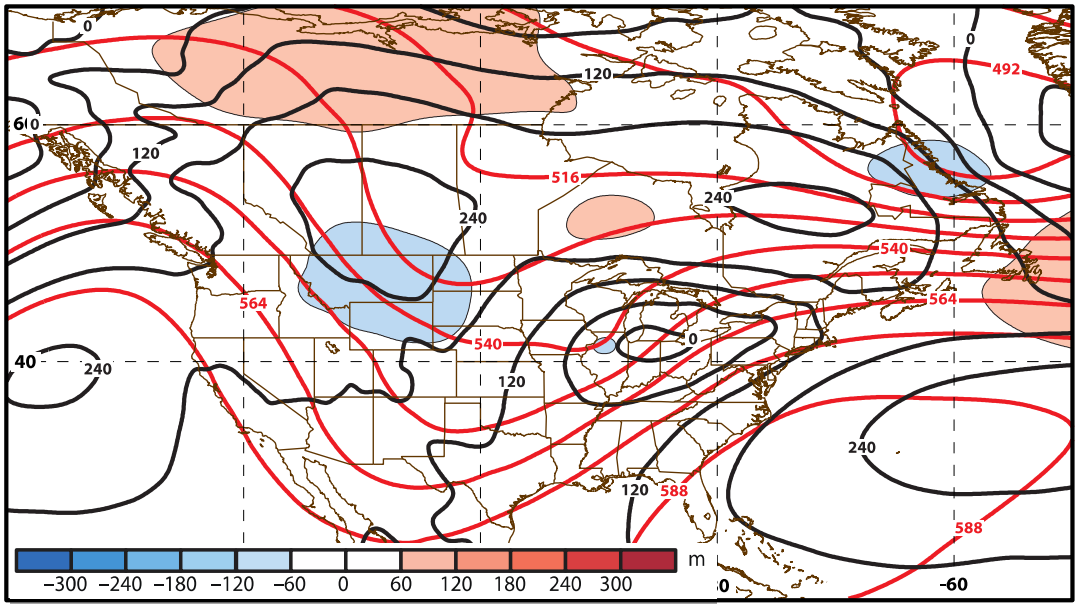
Difference in 500 hPa Geo. Height from forecast initialized 48-h earlier (m; shaded)

850 hPa Geo. Height (m; black)

850 hPa Pot. Temp. (K; red)

Difference in 850 hPa Pot. Temp. from forecast initialized 48-h earlier (K; shaded)

22–23 December 2013 Ice Storm

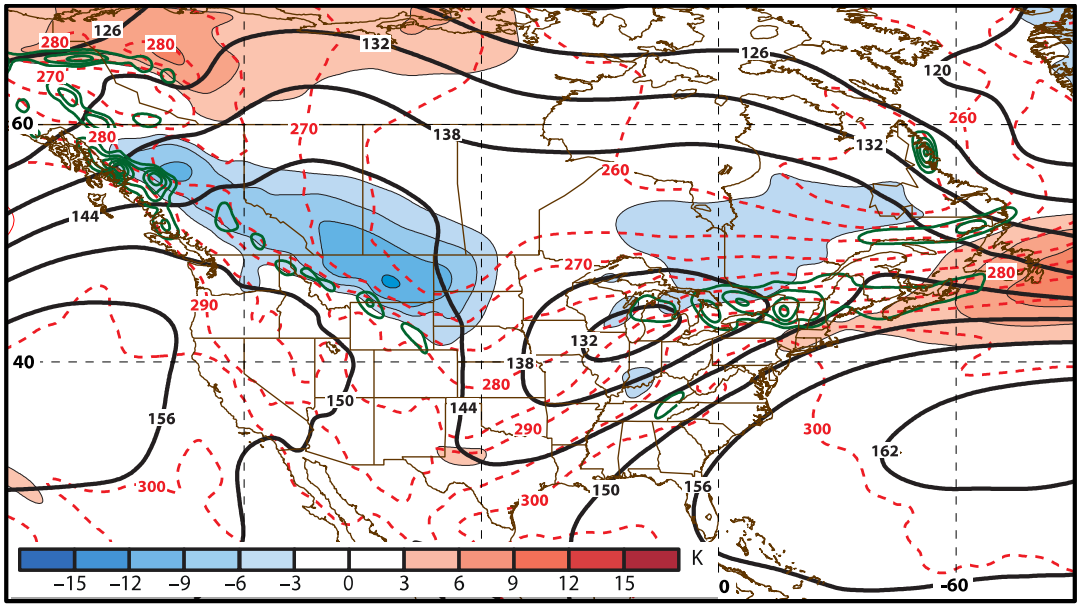


20 December – 48 h

1000 hPa Geo. Height (m; black)

500 hPa Geo. Height (dam; red)

Difference in 500 hPa Geo. Height from forecast initialized 48-h earlier (m; shaded)

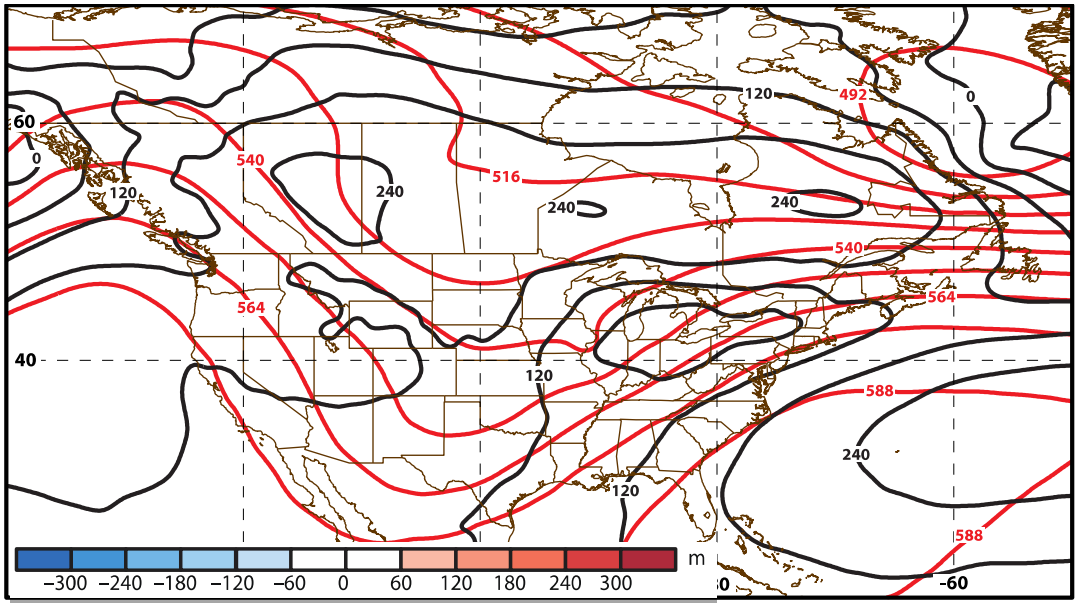


850 hPa Geo. Height (m; black)

850 hPa Pot. Temp. (K; red)

Difference in 850 hPa Pot. Temp. from forecast initialized 48-h earlier (K; shaded)

22–23 December 2013 Ice Storm

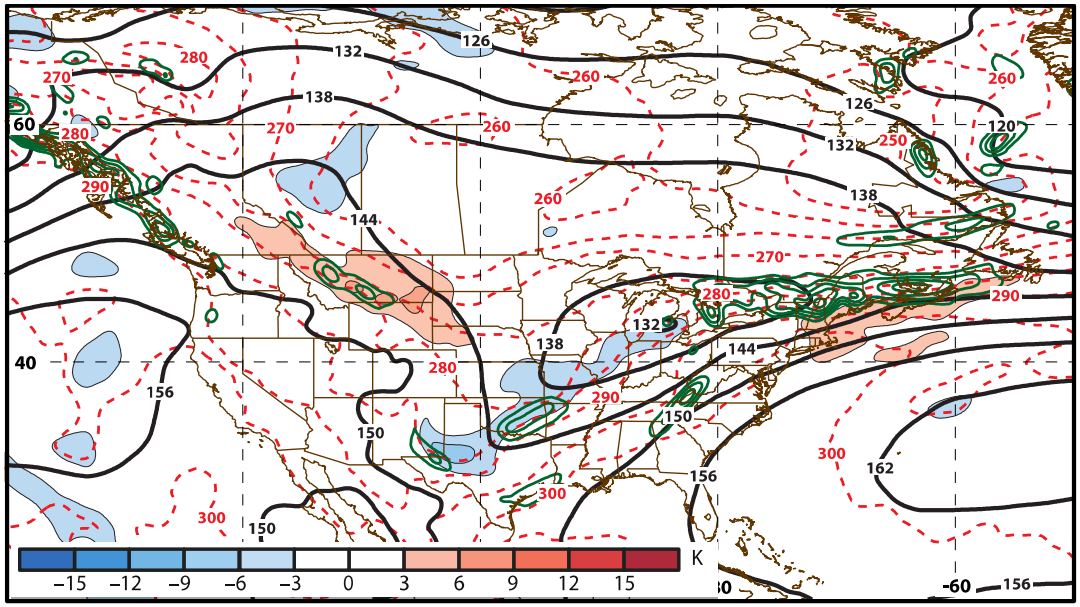


22 December – 00 h

1000 hPa Geo. Height (m; black)

500 hPa Geo. Height (dam; red)

Difference in 500 hPa Geo. Height from forecast initialized 48-h earlier (m; shaded)



850 hPa Geo. Height (m; black)

850 hPa Pot. Temp. (K; red)

Difference in 850 hPa Pot. Temp. from forecast initialized 48-h earlier (K; shaded)

Case Summary

- Forecast spread decreased sharply **96-h prior to the event** throughout the eastern United States.

- Forecasts with a lead time greater than 96-h exhibited considerable uncertainty in the **location and strength of the surface cyclone**.

- Forecasts exhibited uncertainty with respect to the **location, strength, and magnitude of frontogenesis** along the baroclinic zone as little as 48-h prior to the event.

Anticipated Research Efforts

Identify extreme **temperature**, **precipitation** events.

Anticipated Research Efforts

Identify extreme **temperature**, **precipitation** events.

Perform a composite analysis on each event type to determine the **antecedent environments** that favor the development of an EWE.

Anticipated Research Efforts

Identify extreme **temperature**, **precipitation** events.

Perform a composite analysis on each event type to determine the **antecedent environments** that favor the development of an EWE.

Examine **8–10 day forecast skill** for EWEs that fall into each event type.

Anticipated Research Efforts